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THE METEOSAT SYSTEM

H. Felix

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NOTICE

This paper gives a summary description of the METEOSAT system as defined after two years of research at CNES. Further study may involve modifications in certain of the features indicated herein, and the latter should not be regarded as final.

THE METEOSAT SYSTEM

H. Felix

ABSTRACT. The French METEOSAT weather satellite and associated ground systems are described. Operational characteristics of the system are given, as well as a weight and power breakdown of the satellite. An over-all program plan is presented. Launch is presently scheduled for 1975 aboard a THOR rocket. A large number of ground stations are contemplated.

I. Survey of the METEOSAT System /1.1*

1.1. The METEOSAT project

1.1.1. METEOSAT is the name of a space system under study at France's CNES. Its primary component is a fixed position satellite situated at a longitude of 10-30° E which would constitute one of the elements of a world-wide weather observation network (Figures 1.1. and 1.2.).

Launching, currently scheduled for early 1975, would be preoperational in character.

The satellite would be able to communicate with several types of Earth stations, corresponding to its different meteorological missions.

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*Numbers in the margin indicate the pagination in the original foreign text.

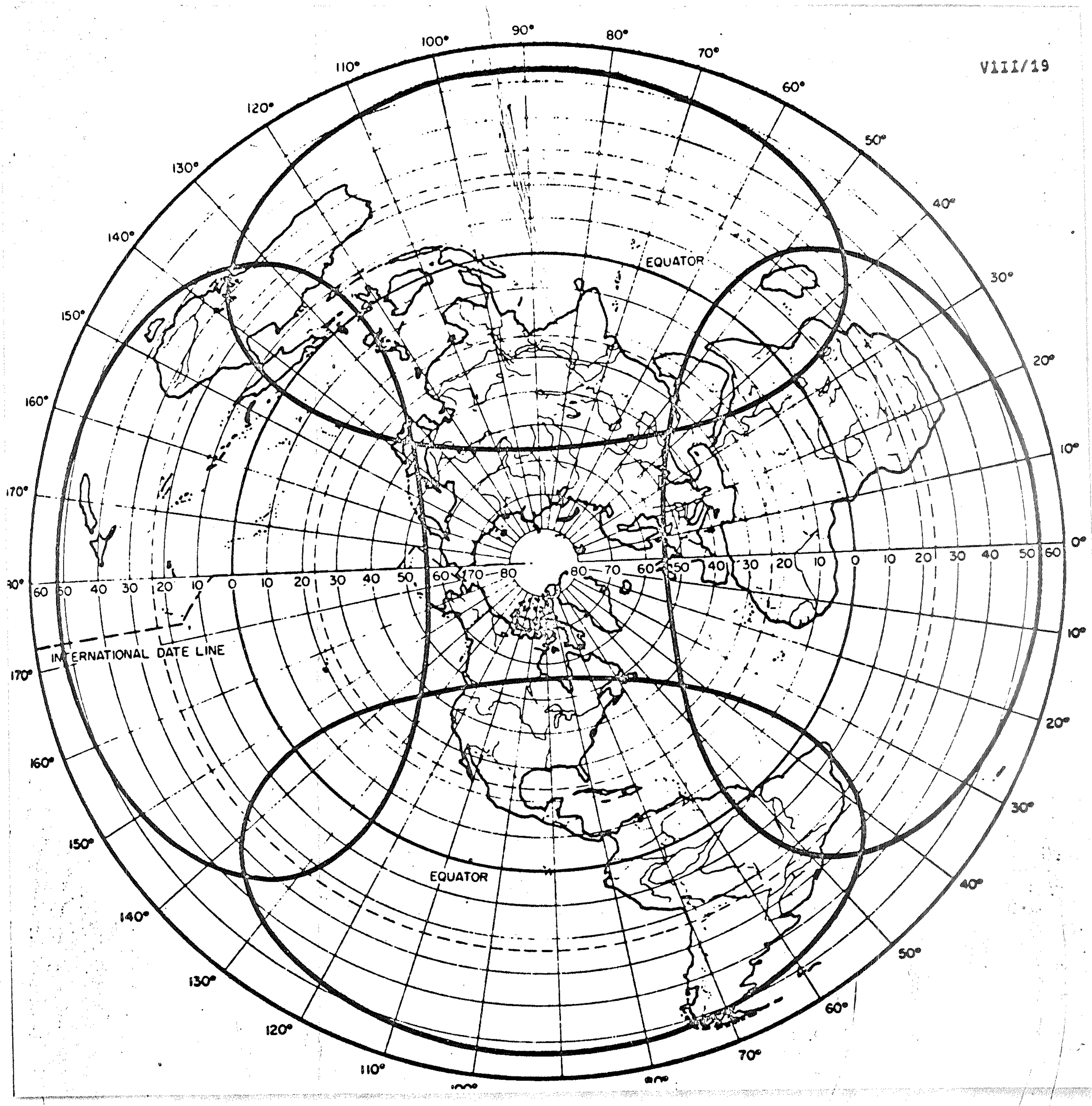


Figure 1.1. World-wide observation network for four fixed position satellites.

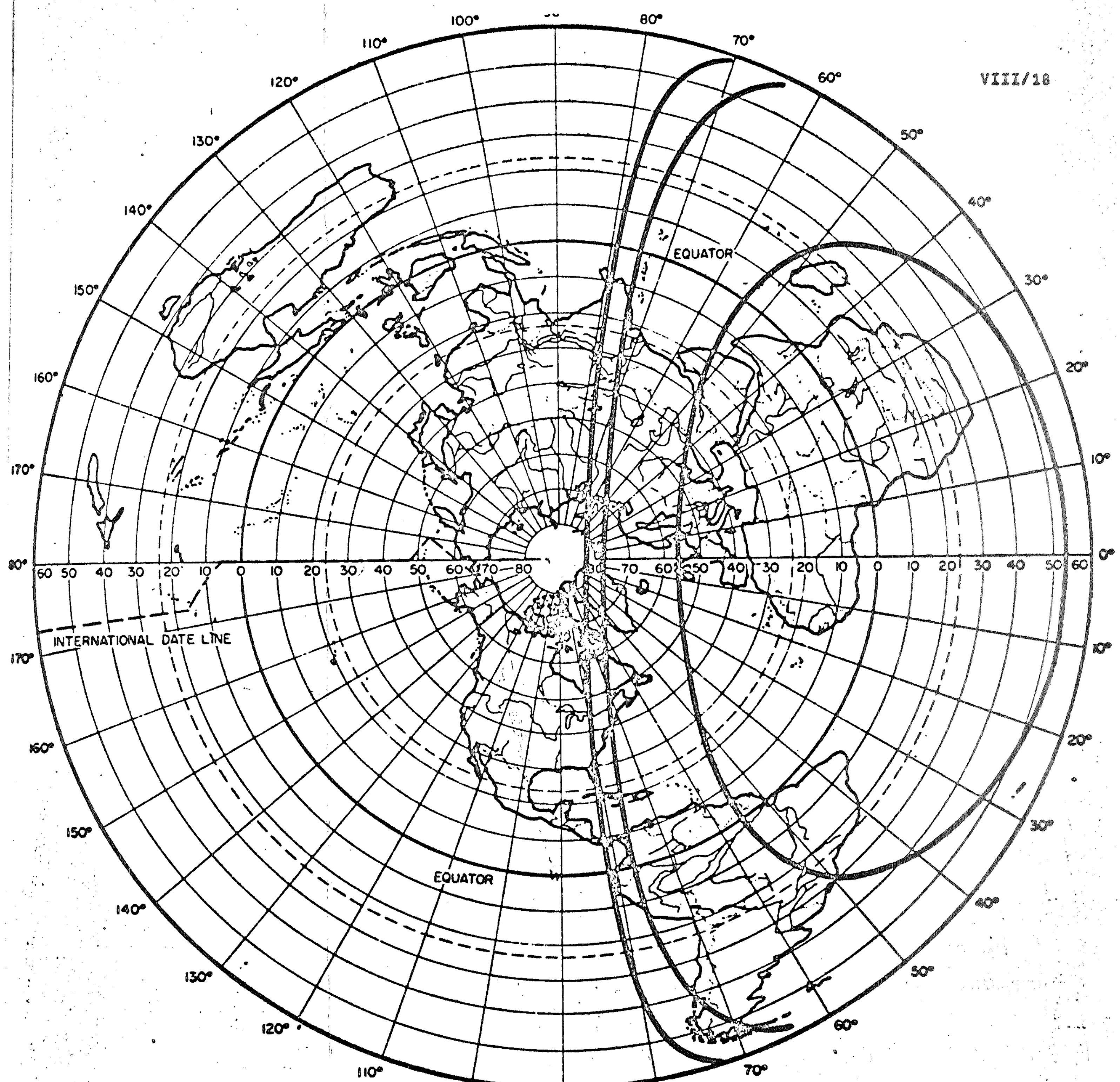


Figure 1.2. METEOSAT satellite to be located between 10° and 30° E longitude. Figure shows location at 0°.

1.1.2. Primary mission of METEOSAT

The satellite's primary mission would be to record the Earth's cloud covering by both visible and infrared radiation with resolutions of approximately three and six km. The corresponding information would be transmitted directly to the ground for immediate computer analysis or simple visualization.

Each composite image (2500 lines for infrared and 5000 for visible) would last approximately one half hour when a new analysis could begin.

Transmission to the ground would normally be accomplished by a small output on-board transmitter. Reception would require a station with a large-diameter antenna (12 m). The central station would be located in France. At certain times each day, image transmission would occur at a large output, to be picked up by simpler stations with 4.5 m antennas.

These "principal" stations are to be situated so that the satellite is observed at an elevation greater than 10°. /1.2

Since image quality depends heavily on satellite motion, utilization of all the sighting details would probably be possible only after ground correction by computer: such pre-processing using data on real attitude and position of the satellite would provide improved images. The corrected images would have to be used by computers, as any method of visualization would degrade them.

The raw images received on the ground would probably be of sufficiently good quality to be reproduced directly on photographic paper for immediate use.

The infrared images should enable us to draw up a temperature chart with a deviation on the order of 1°; they also have the great advantage of giving the picture of cloud coverings at all times of the day.

The more detailed visible image, on the other hand, would show an unusable shadow zone for a great part of the day.

A more detailed description of the mission and the means of implementing it are given in Section II.

1.1.3. The transmission objective

The second mission of METEOSAT is to provide for the dissemination from the central station of different types of meteorological data, to be relayed by the satellite.

Thus, one could retransmit the differentiated, preprocessed high-resolution images of the primary mission to the principal stations.

The retransmission channel would also be compatible with the wefax modu- /1.3
lation standard which could be used in transmitting reduced resolution (800 lines) images or charts, without half-tones, to the less complex local stations which could reuse certain elements of the current APT stations adapted for S-band reception.

1.1.4. The data-gathering mission

It is also anticipated that the satellite will be used as a relay between the central station and the data-gathering platforms scattered throughout the Earth zone covered by the satellite (satellite seen with an elevation of more than 10°). These could be weather buoys, ships, or automatic Earth stations. The stations fall into three different types with corresponding different connection modes: certain stations would send warning signals at unspecified times; when these signals are received, an interrogation message would be sent by the central station to the station giving the alert to request a detailed description of its situation.

Other stations would transmit only in response to interrogation.

Most of the platforms would operate in shifts according to synoptic times.

The system studied would have a "capacity" of 4000 platforms.

1.2. Current state of definition (15 February 1971) /1.4

The definition studies on the METEOSAT system (phase B) are to be completed in June, 1971. At that time, all options are to have been considered, and the missions will be final. Studies on the optical apparatus for sightings (radiometer) have gone forward, and now are in phase C.

In July, if the decision to complete the project is confirmed, detailed planning of all satellite and station equipment will be initiated.

System evaluations began in early 1969. Directed and coordinated by CNES, the research was carried out in conjunction with the National Meteorology and the Dynamic Meteorology Laboratory of CNRS and with the cooperation of several French industrial firms and research centers.

The following sections give a survey of the essential characteristics of the system elements required to meet the stated objectives as defined on 15 February 1971.

1.3. General make-up of the system /1.5

The diagram on page 1.7 shows the total space system, the different connections between its components as well as their principal features. The connection numbers refer to the three missions and to the operational connections (telemetry, remote control, tracking).

Connections of the three-system missions are provided for in the hyperfrequency band (1700-2000 MHz). Nevertheless, for data-gathering it is anticipated by way of an option to provide for satellite-platform connections in the UHF band (400-460 MHz).

The operational connections are accomplished in the VHF band with network stations Diana and Iris.

The connections will be given in detail in the following sections.

1.4. Several operational limitations /1.6

Operational limitations will have to be determined before launching.

Some of them can already be stated.

The first test sightings will probably be possible only three weeks after launch.

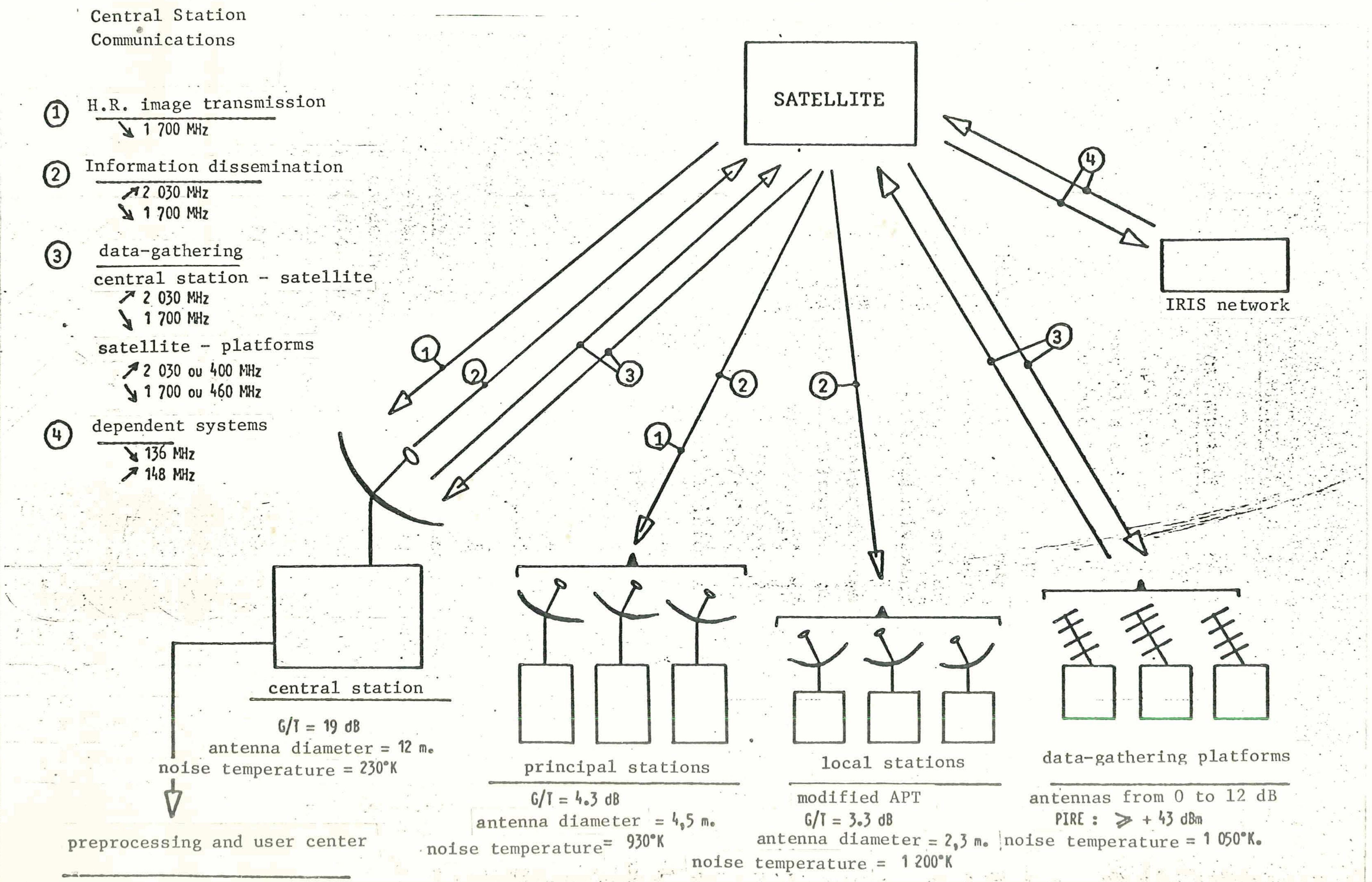
Once the satellite is in position, an average of one fine attitude correction a day and one orbital connection a month are anticipated. Right after these corrections, the images will probably be their best (after nutation suppression, of course).

In principle, sightings will be able to continue 24 hours a day with low output direct transmission. In practice, the number of sightings will probably be limited by the availability of personnel for the stations.

The usage time for the on-board high-output transmitter will be shared among the three missions in accordance with a program to be set up by all interested users.

The battery in the satellite will allow only a very greatly reduced mission during eclipses.

METEOSAT: SPACE SYSTEM AND RADIO COMMUNICATIONS DIAGRAM



II. FIRST MISSION — SIGHTING

2.1. General presentation

/2.1

The first mission of the METEOSAT system is the decisive one for the system: it is the one which in practice determines the general characteristics of the satellite.

Sighting is accomplished by a large telescope mounted aboard the satellite. The Earth images are explored line-by-line at the very slow rate of 100 lines per minute, transmitting information to the ground in real time with a relatively small pass band.

Rotation of the satellite around a North-South axis, and consequent rotation of the telescope, permits sweeping of an East-West line. Since the Earth is seen from the satellite through an angle of 18°, the time spent by the telescope's sighting axis in covering the Earth is at the most 1/20 of the satellite's rotation period; during each rotation, the information received by the radiometer is significant only for 1/20 of the time. It is "drawn out" in a ratio of 19 before transmission to the ground to minimize the pass band.

Moving from one line to the next is done by rotating some of the telescope mirrors through an angle corresponding to the distance between lines.

The final quality of the images reconstituted on the ground is very dependent on the "geometry" of the system, that is to say, as much on the precision of maintaining satellite position as on axis orientation accuracy, precession movements of the axis, and regularity of rotation.

These points will be taken up in greater detail later.

2.2. Radiometer /2.2

2.2.1. General objectives

The radiometer is the instrument which allows us to carry out the sighting mission of the satellite. Its essential objective is to obtain, in a period of close to 25 minutes, two simultaneous images of the Earth's disk:

— one, in the spectrum range of 10.5-12.5 μ, with a spatial resolution at the subsatellite point on the order of 6 km.

— another, in the spectrum range of 0.5-0.7 μ, with a spatial resolution on the order of 3 km.

For the first channel, it would be desirable to have an absolute temperature measurement with a precision on the order of 1° K in a field of 290° K.

For the second channel, a signal-to-noise ratio on the order of 100 for an Earth albedo of 100% is desired.

During eclipses, image loss for a maximum term of two hours is acceptable.

The Earth's field is analyzed line-by-line. The satellite's own rotation causes sweeping of the line, and a mechanism inside the radiometer allows progressive rotation of all or part of the optical system in order to describe all the image lines.

2.2.2. Detectors

A difficult problem is posed by the detectors. In fact, in the infrared channel, considerations of detectivity, time constant, and dimensions in practice require the use of a HgCdTe type quantum detector whose normal operational temperature is around 80° K. Obtaining such a temperature for two /2.3
years aboard a space vehicle would correspond to prohibitive requirements,

assuming a system of active refrigeration or refrigerant storage. One must imagine a completely passive system enabling us to obtain this temperature by radiant coupling with cold space. The limitations associated with such a system are severe: significant dimensions, experimental verification of performance difficult from the ground, possible need for complete reversal of satellite every six months to limit perturbations due to the Sun in the thermal equilibrium of the system.

The following table shows the characteristics of the infrared detector:

Dimensions	80-110 μ square
Spectrum sensitivity	response peak near 11.5 μ at 77° K; the peak moves toward short wave lengths as temperature increases
Response factor	approximately 1000 V/W at optimal polarization
Time constant	$\leqslant 3\ \mu s$.
Specific detectivity	$\geqslant 5 \cdot 10^9 \frac{cm\sqrt{Hz}}{watt}$ averaged for 10.5-12,5 μm for $T < 110°K$ at 800 Hz

2.2.3. Sighting characteristics /2.4

In view of the objectives of the scientific mission and the performance of available detectors, a study of the optical system makes the following characteristics desirable:

General characteristics

— Interval between lines	:	$1.25.10^{-4}$ radian
— Number of lines	:	2500
— Number of points per line	:	between 2048 and 2500
— Image duration ($\pm 9°$ sweep)	:	25 minutes
— Image recurrence	:	2 per hour
— Satellite rotation	:	100 RPM
— Pass band in space frequencies	:	2800 cycles/radian isotropic

Instrument characteristics

— Catadioptric system	:	Ritchey-Chrétien type
— Useful primary diameter	:	40 cm
— Usable surface	:	1000 cm^2
— Telescope focal length	:	2.50 m approx
— Focal length after reduction	:	60 cm approx
— Transmission coefficient at 11μ	:	0.6 approx
— Transmission coefficient at 0.6μ	:	0.45
— Optical quality	:	better than Rayleigh criterion at 11 μ

Detection characteristics and performance

— Calibration of measurement connection close to 1%.

— Pass band in infrared channel	:	29.4 kHz
— Pass band in visible channel	:	58.8 kHz

— Filtering 18 or 24 dB/octave.

An infrared detector is placed redundantly in the neighborhood of the first, and intervenes when the first fails.

Moreover, a system of in-flight refocussing, for both channels, enables us to correct possible errors in adjustment.

2.2.4. Current conception of the radiometer /2.5

The current conception of the radiometer points up the following principal characteristics:

Optical system

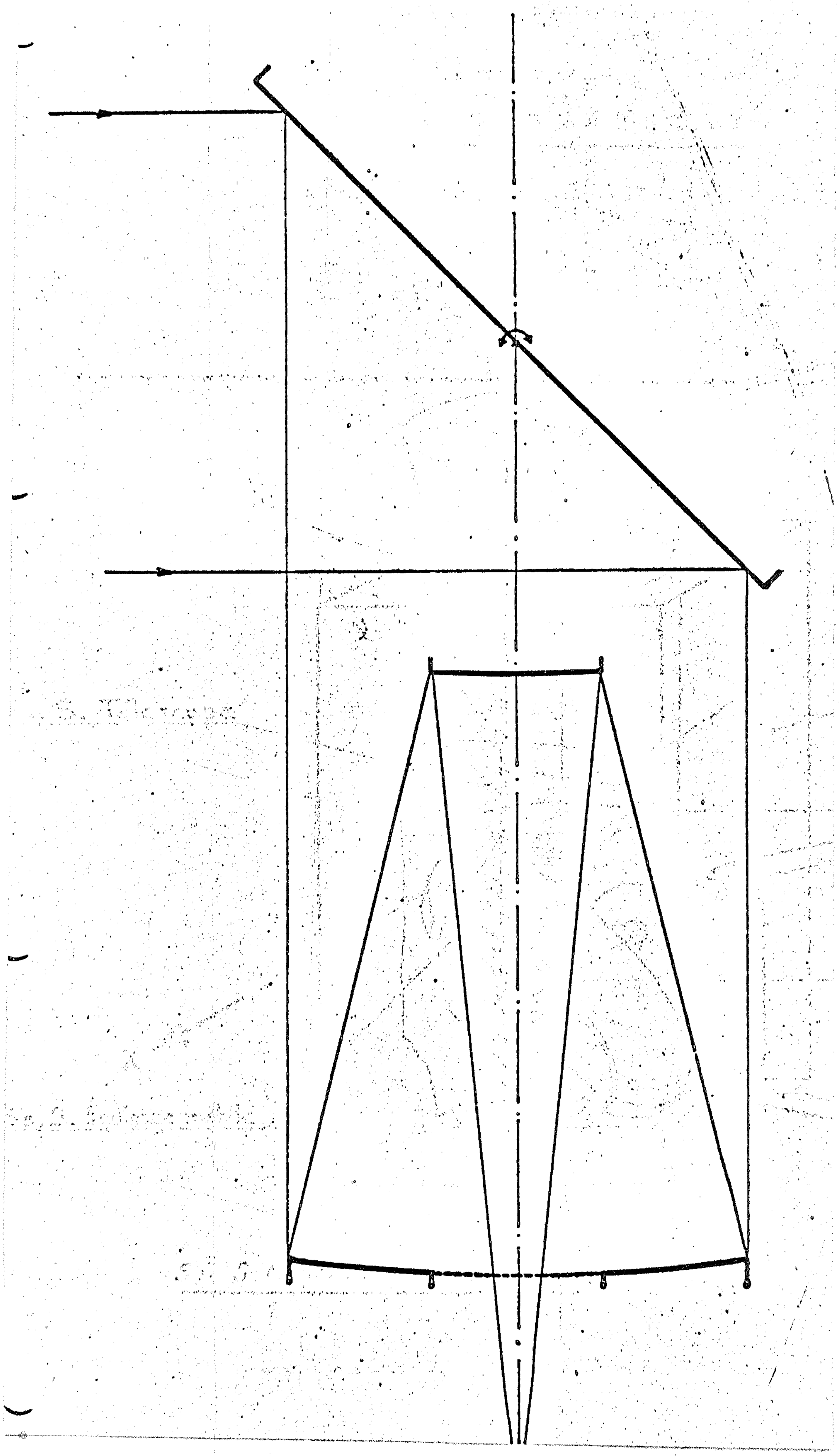
— Ritchey-Chrétien type.
— Primary mirror with Ø 40 cm, open to f/2.
— Material: CER-VIT lightened by more than 60%.
— Rate of secondary linear occulation: slightly more than 0.30.
— Good image field $\geq$ 20 mm.
— Channels separated in the field.

Instrument

— Mass on the order of 45 kg (including structure, baffle, mechanisms, thermal control).
— The radiometer is thermally insulated from the rest of the vehicle. Normal working temperature in orbit is close to 40° C.
— Electric power consumption: average less than 16 W.

The life-span objective for the instrument is more than two years.

Two types of telescope currently being compared are shown in Figures 2.1 to 2.4 in the following pages.



Siderostat Scale: 1/5

Figure 2.1.

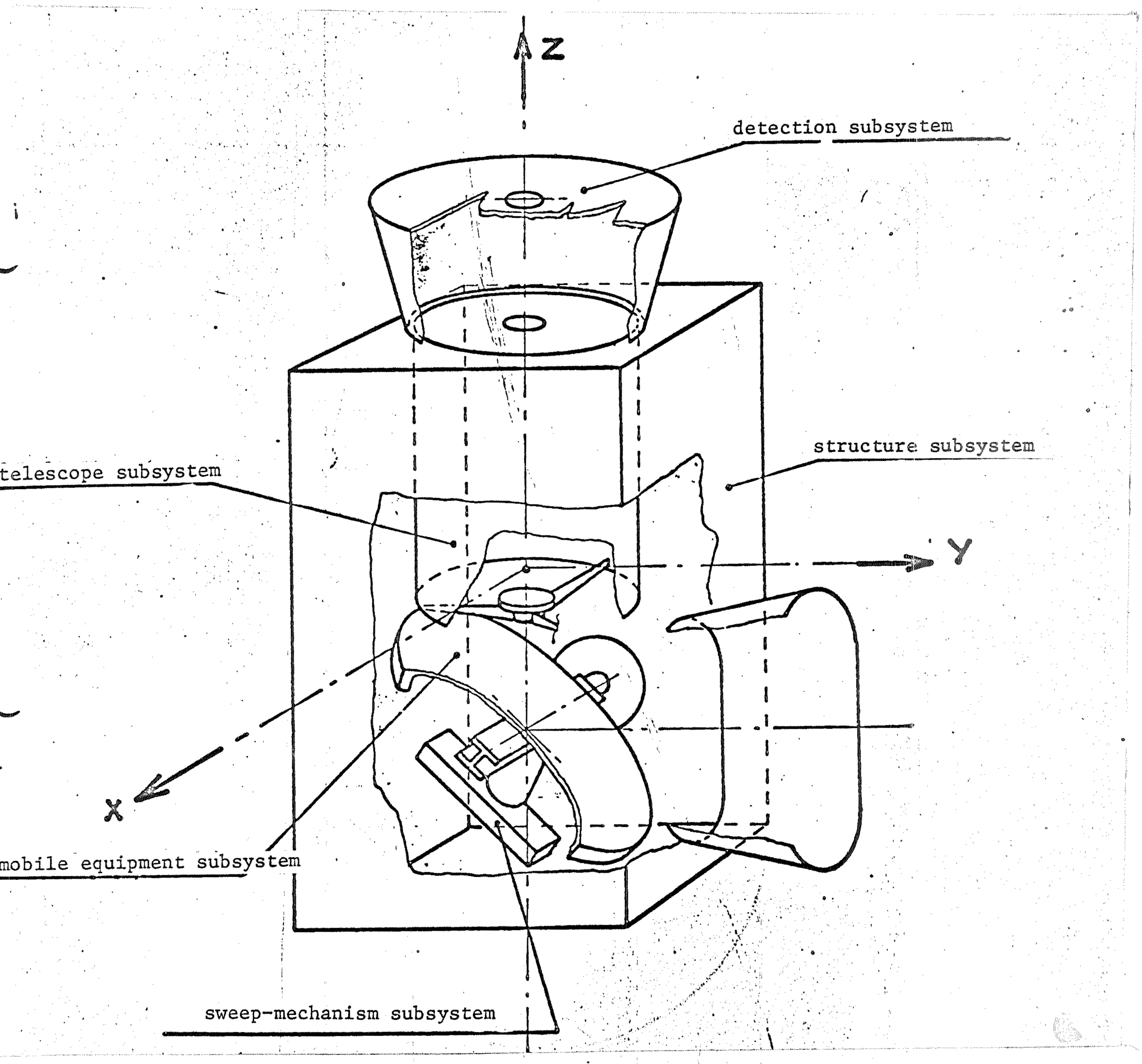
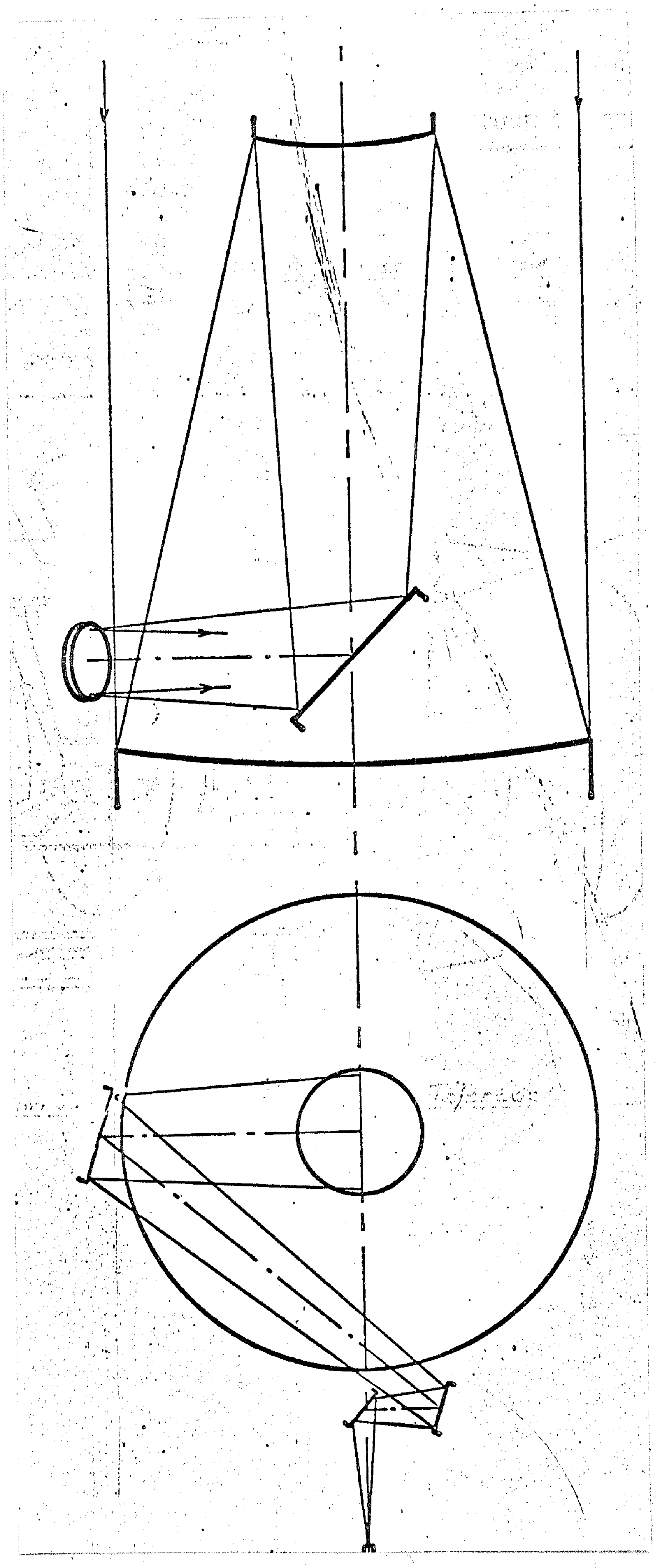

Z
detection subsystem
structure subsystem
telescope subsystem
Y
X
mobile equipment subsystem
sweep-mechanism subsystem

Figure 2.2.



Earth Setting Scale: 1/5

Figure 2.3.

Earth Setting

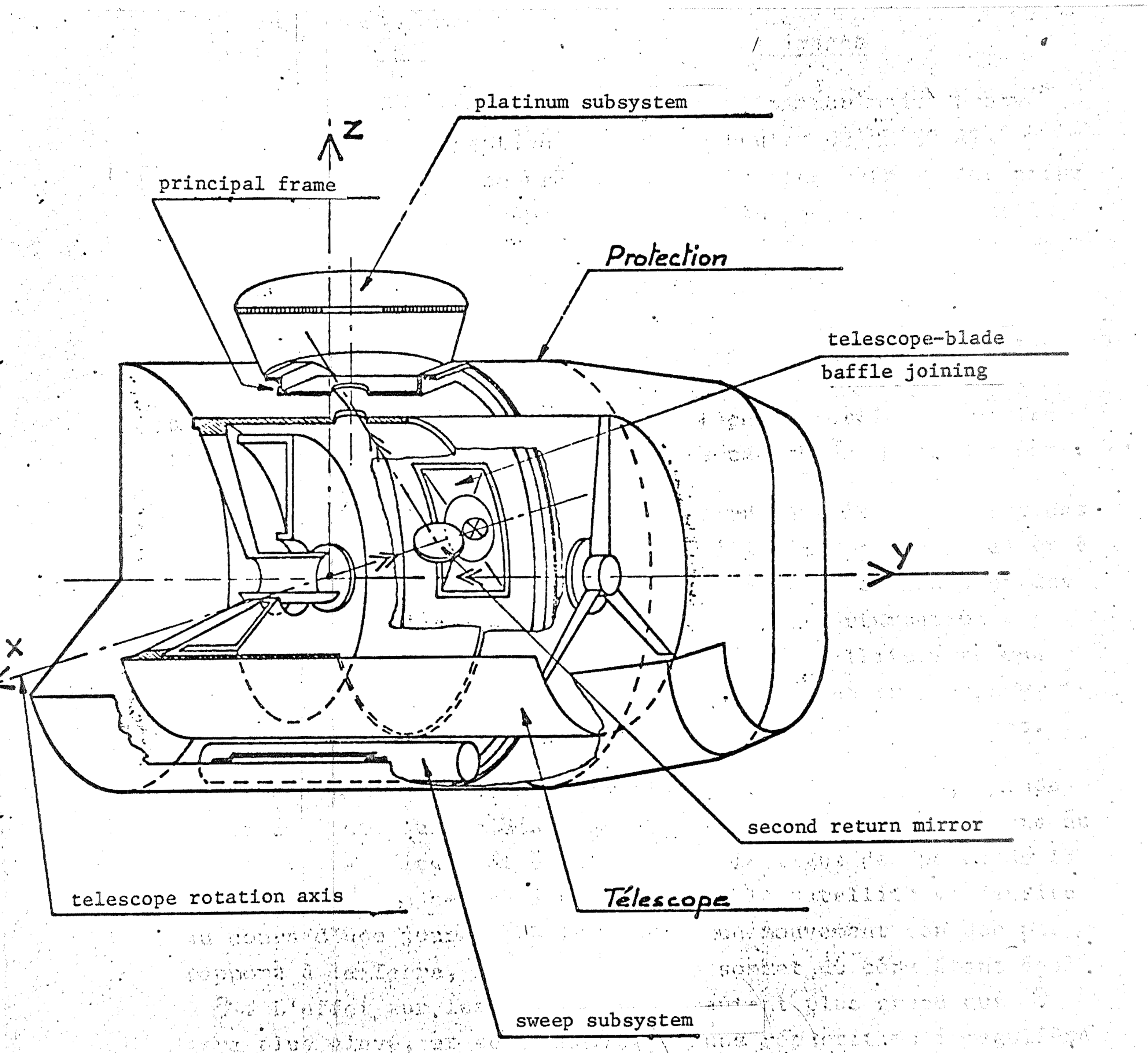


Figure 2.4.

2.3. Geometric characteristics of the image and induced limitations on attitude and orbit /2.10

2.3.1. Causes of image distortion

It is desirable for a modestly equipped user to be able to receive METEOSAT's crude images and then establish a precise correspondence between the parameters of a METEOSAT measuring point (line number and point number) and the two geographical coordinates of a point on the Earth. The only tolerated corrections are simple geometrical transformations: translation and rotation of the whole, which can be done manually by the user.

These operations will certainly not be enough to correct all the geometric errors derived from the three causes of perturbations:

1. The instability of the satellite due to poor adjustment of orbital parameters (eccentricity, inclination and period) and their drift under the combined effects of the Sun, the Moon and the irregularities in the Earth's potential. This perturbation leads to small movements in the subsatellite point with a period of 24 hours. If the amplitude of these movements is too great, they will introduce fuzziness effects in the images.

2. Attitude errors in the satellite: two attitude errors exist, distinguishable by their periods. If the axis of the satellite, instead of being parallel to the line of the poles of the Earth, makes an angle θ with them, the satellite will describe in the course of 24 hours a conical movement with respect to the Earth, the half-angle at the top of the cone being equal to θ. The effect on image quality will increase, the greater angle θ becomes, and will appear as an irregular distribution of points.

Perturbations can create small, rapid nutation and precession movements, which, if not suppressed, will distort the edges of the images and scramble the lines.

3. Errors in rotation synchronization may cause sampling irregularities. /2.11

The objective decided upon is to limit these perturbations, so that after correction by translation and rotation of the whole, a sample with a given rank will correspond to the geometrical point actually seen within a certain tolerance.

2.3.2. Limitations on the satellite

Three cases are considered:

1. In the short term, for a hundred lines, it is desired that the details not be distorted, which implies that the actual sweeping "grid" have the same shape as the ideal grid. Thus, in the neighborhood of one point, the sampling points should be at a slight distance from their theoretical position. This leads to the specification that the nutation be less than 5" of arc. For synchronization of the clock controlling sampling, the reference mark should never slip by more than 10^{-5} radians between two successive lines, which presupposes that angular accelerations of the satellite be limited to 3.10^{-6} rd/s^2.

2. In the medium term, we wish to be able to measure the velocity of a cloud by referring to its movement in five consecutive images with an accuracy of 5 km/h. This means we must be able to evaluate a 10 km. cloud movement in two hours. This condition determines certain parameters:

— Satellite axis orientation: less than 1' arc from North-South,
— Longitude drift less than 0.1° per day,
— Eccentricity less than 1.7×10^{-3},
— Orbital inclination less than 0.2°,

and limits the number of corrections to one a day for attitude and one a month for orbit.

3. In the long term, we seek to know with a certain degree of accuracy the absolute geographical position corresponding to a given sample. The desired accuracy is on the order of several tens of kilometers. /2.12

Recapitulation of constraints

Orbits
- $e < 1{,}7.10^{-3}$
- $i < 0{,}2°$
- East-west drift < 0.1°/day
- Orbital correction: 1 per month

Attitude
- North-south orientation: better than 1' arc
- Nutation < 6"
- Angular acceleration of satellite $< 3.10^{-6}$ rd/s^2.
- Attitude correction: 1 per day

It is difficult for the satellite to observe these constraints. In any event, users requiring image accuracy may always, at the price of a moderate delay, obtain a rectified image of much better geometrical quality.

2.4. Transmission of images to the ground /2.13

The analog information from the detectors in the radiometer is amplified, filtered, then numbered and stored temporarily in the memory for 1/20 of a satellite rotation. During the rest of the rotation, they are reread, coded in bi-phase PCM, and come to modulate in phase an approximately 1700 MHz carrier wave.

There are two possible transmission modes:

1. Transmission at reduced output ($\simeq 2,5$ W) permitting communication with the central station or equivalent stations with a G/T of 19 dB/° K.

2. Transmission at greater output ($\simeq 20$ W) for communication with principal stations with G/T of 4.3 dB/° K. The 20 W transmitter used is the one from the mission 2 and 3 transponder with which mission 1 functions in shared time in this mode.

Energy is radiated toward the Earth by a counter-rotating antenna with electronic commutation with a maximum axis gain on the order of 18 dB.

On the ground, the signals received are switched back to allow either transmission by ground lines at a high rate to the preprocessing center or direct visualization.

Figure 2.5 shows a block diagram of the transmission connections aboard the satellite.

Figure 2.6 gives the principal characteristics of the connection.

The format of the image lines transmitted is made up of:

— one synchronization word,
— 2500 brilliance words in the form $\boxed{V_1 \,|\, V_2 \,|\, IR \,|\, V_3 \,|\, V_4}$ where V_i are the visible 5 bit samples and IR has 8 bits,
— various operational words during the 1/20 turn not used for the image. /2.14

Figure 2.7 shows the communication balances between the satellite and the central or principal stations.

SYSTEMS OF RADIOMETER DATA LINK

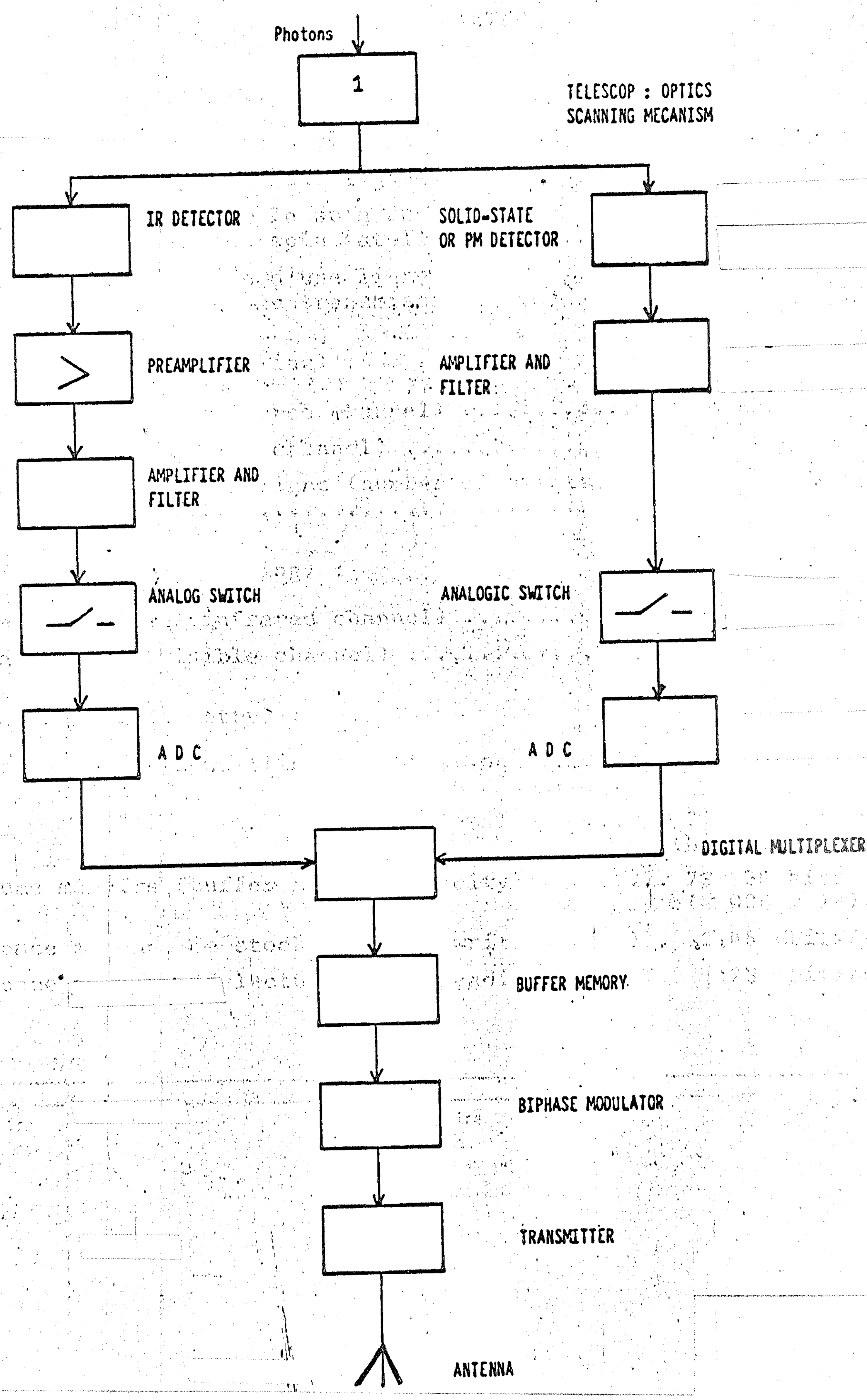


Figure 2.5.

CODING SUBSYSTEM

Timing:	
Spin period	600 ms (T)
Line duration	30 ms (T/20)
Synchronization: on spin satellite	
Line transmission time	570 ms (19 T/20)
Sampling:	
Infrared channel	80 kHz
Visible channel	160 kHz
Number of points for line	2 500
Amplitude coding:	
Infrared channel	8 bits
Visible channel	5 bits
Telemetry:	
Line organization	2 500 points of 28 bits
Total	70 000 bits (brilliance only)
Buffer memory capacity	73 728 bits (4 096 X 18)
Mean writing rate	2.45 Mbits/s
Mean reading rate	129 Kbits/s

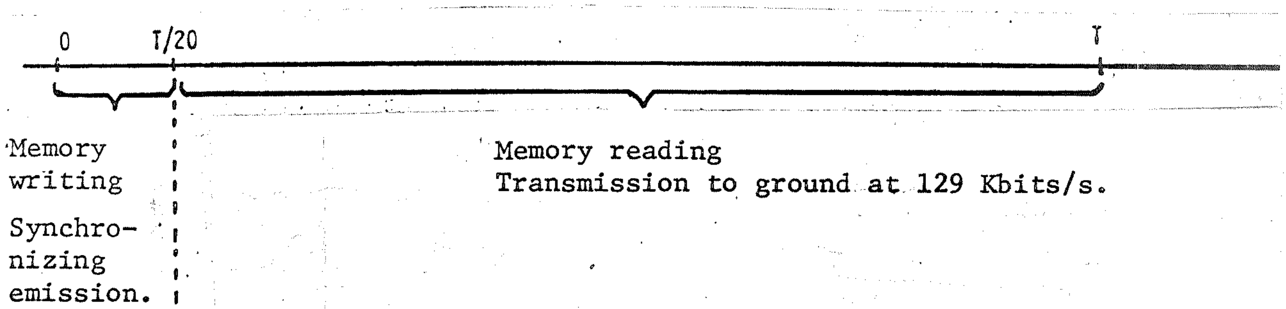


Figure 2.6.

SATELLITE

Communications Balance

SATELLITE ⟶ central station			SATELLITE ⟶ principal stations	
F/N ($p_o = 10^{-6}$)	10,6 dB		10.6 dB	
rate	51.15 dB		51.15 dB	
PROPAGATION	-188.9 dB	(Elévation 30°)	- 189.5 dB	(Elévation 5°)
satellite-ground gain	43.5 dB	(ø 12 m)	35. dB	(ø 4,5 m)
hyperfrequency loss	- 0.7 dB		- 1. dB	
polarization loss..	- 0,5 dB		- 1. dB	
atmospheric loss	- 0.1 dB	(Elévation 30°)	- 1. dB	(Elévation 5°)
noise	-205.0 dB	(T = 230°K)	- 199.0 dB	(T = 930°K)
minimum PIRE.......	3.25 dB		20.25 dB	
output (2.5W)	4. dB		(20 W) 13. dB	
modulation loss	- 2.5 dB		- 2.5 dB	
carrier wave 25% ...	- 1.25 dB		- 1.25 dB	
hyperfrequency loss	- 4.5 dB		- 4.5 dB	
disorientation	- 2. dB		- 2. dB	
SL antenna gain	18.5 dB		18.5 dB	
PIRE obtained	12.25 dB		21.25 dB	
margin	9.0 dB		1.0 dB	

Figure 2.7.

2.5. On-board equipment synchronization /2.18

2.5.1. Purpose

All equipment in the sighting connection must be synchronized with the rotation of the satellite.

The final quality of the images depends on the quality of this synchronization.

The following must be synchronized:

— telescope sweep,
— line-point sampling,
— memory inputs and outputs,
— counter-rotating antenna operation,
— satellite navigation.

2.5.2. Various solutions

Two solutions have been studied:

2.5.2.1. The first solution is the use of a fixed rhythm clock.

It would then be necessary to allow a margin of time for the duration of image recording and for the duration of image information transmission. These precautions would be required, so that variations in spin velocity do not lead to incomplete Earth sightings or incomplete transmission of information.

Spatial resolution varies with spin velocity. A synchronization impulse must be created which would determine when images were taken in each turn. This impulse would be marked by noise translated by a shift between successive lines.

To be able to recompose the image with the desired accuracy, an ultra-stable clock and a very precise knowledge of the satellite's rotation would be required.

2.5.2.2. The second solution would be to use a "spin clock". This clock, synchronized with the rotation of the satellite, would give a constant spatial resolution if the velocity of the satellite did not vary too rapidly. /2.19

The use of this clock would allow constant image definition as well as a constant transmission format (same composition, but with variable frequency).

The clock uses a synchronization impulse delivered either through the telescope's infrared channel or by an auxiliary sensor, but the effect of the noise of this impulse could be minimized by an integration process.

2.5.2.3. Choice and performance

After a study of the advantages and drawbacks of each solution, the spin clock was selected as the nominal solution.

That solution would allow us to divide the period of rotation into 50,000 equal intervals using a digital counter reaction loop and a VCXO. The loop threshold is a function of cumulative asynchronization error as well as of the noise of the synchronization impulse.

Performance is limited by four types of error which were taken as equal to 1/10 of the resolution element between two consecutive lines:

- VCXO frequency stability in the short term,
- VCXO frequency quantization,
- short-term voltage stability.

The threshold is $\pm$ 2 resolution elements, i.e., the beginings of image pick-up will fall between two distant planes of 4 resolution elements, but the variation from one line to the next will be only 1/20 resolution element.

III. MISSIONS 2 and 3

The satellite contains a repeating system associated with a counter-rotating antenna whose different operation modes permit us to carry out missions 2 and 3 in shared time and eventually distance-measurements necessary for fine tracking of the satellite. Missions 2 and 3 respectively are:

— Retransmission of documents for users located at any point in the zone covered by the satellite,

— Data-gathering picked up by fixed or mobile (ship) platforms located at any point in the zone covered by the satellite.

3.1. Retransmission of documents

The disseminated documents are transmitted from the central station and relayed by the satellite's repeating system. Two operational modes (non-simultaneous) are possible, but they differ in the nature and quality of transmitted documents.

We can disseminate:

— either "visible" or "infrared" high-resolution images. In principle this will be the type of image supplied by mission 1 and previously processed,

— or various meteorological documents (maps, for instance).

In this case, compatibility with the WEFAX mission is sought as defined for the SMS project.

3.1.1. Retransmission of high-resolution images /3.2

Let us recall that mission 1 allows for the possibility of transmitting rough images with high output toward receiving stations called principal stations. This possibility is very interesting in that the quality of rough images allows us to use them directly in a qualitative manner. If this is not the case, in particular if residual movements of the orbiting satellite are too large, it is necessary to process the images before using them even qualitatively. The processed images are then retransmitted from the central station for the use of the principal stations. This system is diagrammed in Figure 3.1.

Principal communications characteristics:

— The upward central station-to-satellite communication will be at a frequency in the vicinity of 2000 MHz.

— The downward satellite-to-principal station communications will use a frequency in the vicinity of 1700 MHz.

— The type of modulation should allow us to keep the intrinsic qualities of the transmitted signal. Like direct transmission of rough images, retransmission of processed images will use PCM/PM modulation.

— The maximum rate currently anticipated is 130 kb/s. This rate allows us to retransmit in 25 minutes images with the same characteristics as the rough images (format, coding), but studies are underway for the optimization of the retransmission format as a function of the feasibility of visualization systems.

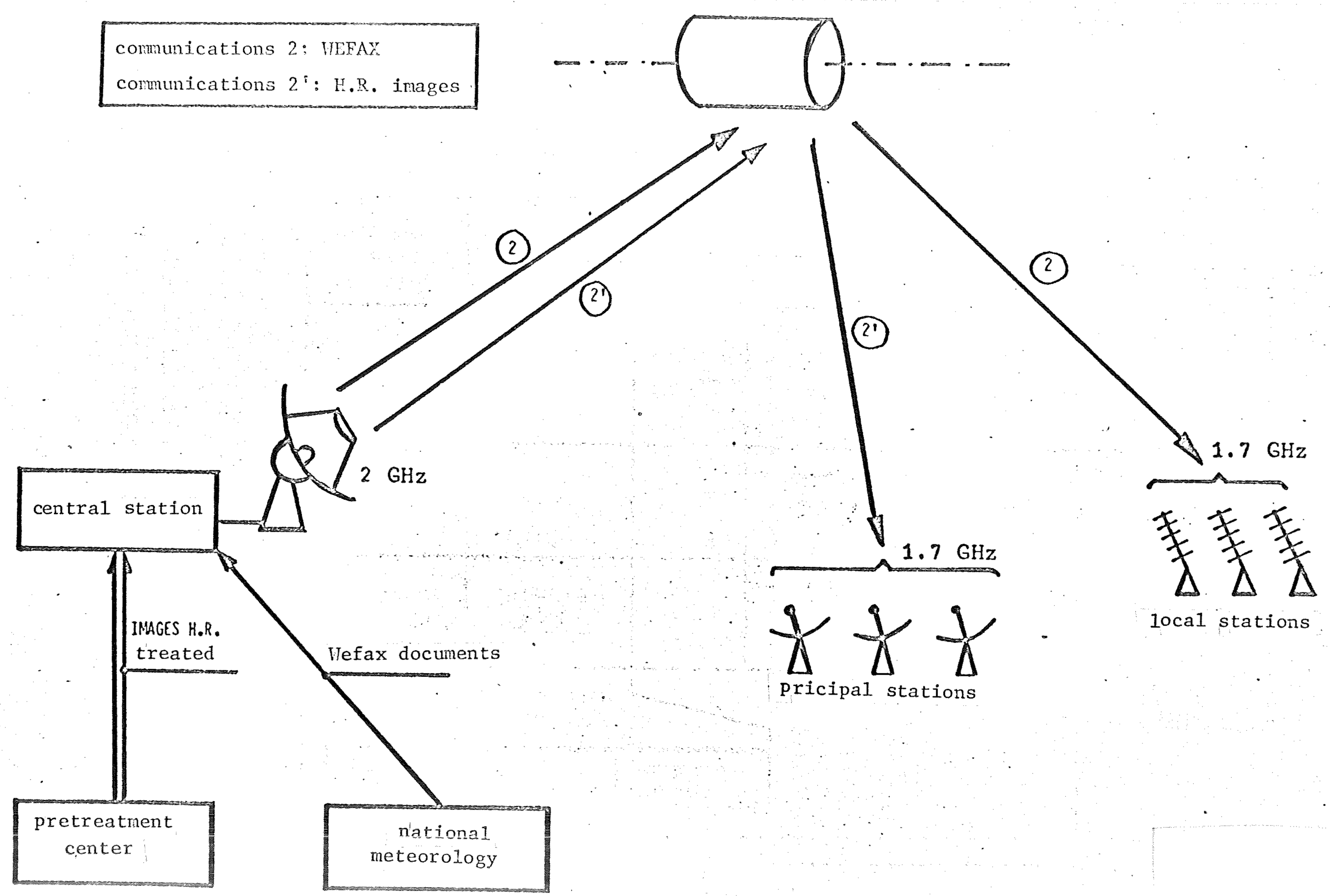


Figure 3.1. DOCUMENT RETRANSMISSION

Characteristics of the principal stations:

— These stations can be set up at any point from which the satellite is higher than 5 or 10°.

— They are equipped with a 4.5 meter diameter antenna with a gain estimated at G = 34 dB, including hyperfrequency losses.

— The maximum temperature at the input of the receiver connection due to this antenna is estimated at T_a = 180°K (cosmic noise, atmospheric noise at 5° from location, hyperfrequency loss, etc...). /3.3

— The overall noise factor of the receiver is estimated at F_b = 5.5 dB, where T_r = 750°K.

— The overall reception temperature is thus: $T_g = T_a + T_r = 930°$.

N.B.: These figures are working hypotheses subject to reevaluation. Actually, the principal stations could be required to receive also images transmitted by the motion satellites of the ITOS series, in which case certain characteristics would have to be altered for better reception performance in particular.

The communication balances are shown in detail in Table I, p. 32.

3.1.2. Retransmission of documents by WEFAX standard

National Meteorology has a network for the dissemination of documents in France and receives information originating in various other countries via international networks. This information exchange is accomplished through PTT communications. The objective of the WEFAX mission is to allow wide dissemination of these documents without the limitations of earth-bound communications.

TABLE I

COMMUNICATIONS BALANCE FOR H. R. IMAGE RETRANSMISSION

1) Satellite-to-Principal Station Links (1,700 MHz) PCM/PM Link — 130 kb/s — Probability of Error 10^{-6}.

EN_o	+	10.6	dB	
Rate	+	51.15	dB	
Propagation	+	189.5	dB	(Elevation 5°)
Gr	-	35.0	dB	(Ø 4.5 m)
Hyperfrequency loss .	+	1.0	dB	
Polarization loss ...	+	1.0	dB	
Atmospheric loss	+	1.0	dB	(Elevation 5°)
Noise	-	199.0	dBW/Hz	
Carrier wave 25%	+	1.25	dB	
Minimum PIRE	+	21.5	dBW	

2) Central Station-to-Satellite Link (2,000 MHz)

Ga	+	44.0	dB	(Ø 12 m)
Hyperfrequency loss .	-	1.2	dB	
Polarization loss ...	-	0.5	dB	
Atmospheric loss	-	0.1	dB	(Elevation 30°)
Transmitted power ...	+	20.0	dBW	
Propagation loss	-	190.2	dB	
Gr	+	14.0	dB	(Satellite, counter-rotating, antenna including hyper-frequency loss).

(table con't. on next page)

TABLE I (CON'T.)

Received power	- 114.00 dBW
Satellite noise power	- 198.8 dBW/Hz
P/N_o	84.8 dB/Hz

Thus, we obtain: 78.8 dB/Hz for the carrier wave (25% of the output)
83.55 dB/Hz for modulation
E/N_o = 32.4 dB/Hz (rate 130 Kb)

allowing a perceptible 20 dB margin with respect to downward communication (E/N_o = 10.6 dB).

Thus, there will be very little degradation of diffusion quality by the upward link.

Documents for dissemination, elaborated or centralized by National Meteorology, are sent off by specialized Earth communications to the central station, where they are put into the proper form and transmitted for the use of local stations.

These local stations are probably similar to current APT receiving stations, that is, we are speaking of relatively crude and cheap equipment. They operate at a frequency near 1700 MHz.

A diagram of the system is shown in Figure 3.1.

Principal communications characteristics: /3.4

— The upward central station-to-satellite communication will use a frequency of approximately 2000 MHz.

— The downward satellite-to-local station communication will use a frequency of approximately 1700 MHz.

— The transmission standard used will be compatible with the WEFAX standard which appears to be used for the American SMS project. In fact, we are speaking of an APT type format and modulation, i.e.: 800 lines x 800 points transmitted in 200 seconds, AM/FM modulation with a 2400 Hz subcarrier wave.

Local station characteristics:

— They can be set up at any point from which the satellite is seen higher than 5 or 10°.

— These stations are equipped with a 2.3 meter diameter antenna with a gain, including hyperfrequency loss, estimated at G = 27.5 dB.

— The overall noise temperature of reception, including noise introduced by the antenna, is estimated at $T_a = 200°K$, and the receiver's own noise with a noise factor of $F_b = 6.5$ dB is:

$$T_G = T_a + T_r = 1200°K.$$

The communications balances are detailed in Table II.

3.2. Data-gathering mission /3.5

The data gathered and transmitted by a certain number of "data-gathering platforms" located throughout the satellite's visibility zone are relayed by the satellite and received by the central station. The messages from all the platforms should be received by the central station in 1-1/2 hour, this 1-1/2 hour cycle being repeated every 6 hours.

3.2.1. Platforms and mode of operation of platforms

The platforms can be of three distinct types:

— Fixed ground platforms,

— Platforms aboard ships,

— Floating, nondrifting buoys.

The problems relative to each of these three types of platform are rather different:

— The fixed ground platforms can be equipped with fixed, relatively directional antennas (stationary satellite).

On the other hand, energy supply problems are particularly bothersome, especially if the platform is quite isolated.

TABLE II

COMMUNICATIONS BALANCE FOR WEFAX RETRANSMISSION

1) Satellite-to-Local Station Links (1,700 MHz) AM/FM Link — FI Band : 30 kHz — FM Demodulating Threshold : 10 dB.

P/N_oW	+	10.0	dB
W	+	44.8	dB (30 kHz)
Propagation loss	+	189.5	dB (Elevation 5°)
Gr	-	28.5	dB
Hyperfrequency loss .	+	1.0	dB
Polarization loss ...	+	1.5	dB
Atmospheric loss	+	1.0	dB
Noise	-	197.8	dBW/Hz (1,200°K)
Minimum PIRE	+	21.5	dBW

2) Central Station-to Satellite Link (2,000 MHz)

Ge	+	44.0	dB (Ø 12 m)
Hyperfrequency loss .	-	1.2	dB
Polarization loss ...	-	0.5	dB
Atmospheric loss	-	0.1	dB (Elevation 30°)
Transmitted power ...	+	20.0	dBW
Propagation loss	-	190.2	dB
Gr	+	14.0	dB (Counter-rotating antenna including hyperfrequency loss)
Received power	-	114.0	dBW

(table con't. on next page)

TABLE II (CON'T.)

Satellite noise output	- 198.8 dBW/Hz
P/N_o	84.8 dB/Hz

In a 30 kHz band let: $P/N_0W = 40$ dB

(30 dB margin with respect to downward link).

— Shipboard platforms are mobile but subject to pitching and rolling and will be equipped with wide-coverage (low gain) antennas. On the other hand, energy supply problems are not critical. Moreover, the constant presence of personnel may make them easier to use.

— Buoys would have to adjust both to low-gain aerials (movements due to swells) and low-output transmitters (energy supply problems). Thus, they pose a particularly acute communications balance problem.

From the operational mode point of view, we note: /3.6

— Platforms transmitting their messages in shifts, synchronized by a clock inside. These platforms require only upward communication (platform-to-satellite).

— Platforms that can be interrogated from the central station. These will require a double communication and will thus be supplied with a receiver. Of the "interrogatable" platforms, a certain number called "alert platforms" will have the capability of spontaneously transmitting a brief alert signal when needed (cyclone, tidal wave) notifying the central station of the need for them to interrogate immediately.

3.2.2. Communications organization and system operations

— The platforms transmitting by shifts are located throughout a certain number n of adjacent channels, the width of which depends on the long-term stability of different oscillators (especially platform clocks). A given channel is used in time-sharing by a number N of platforms, with some margin allowed between the theoretical transmission times of two successive platforms, to take into account the long term drift of the synchronization clocks. This organization is diagrammed in Figure 3.2.

— The "interrogatable" platform receivers are tuned to the interrogation signal carrier wave transmitted by the central station at the start of

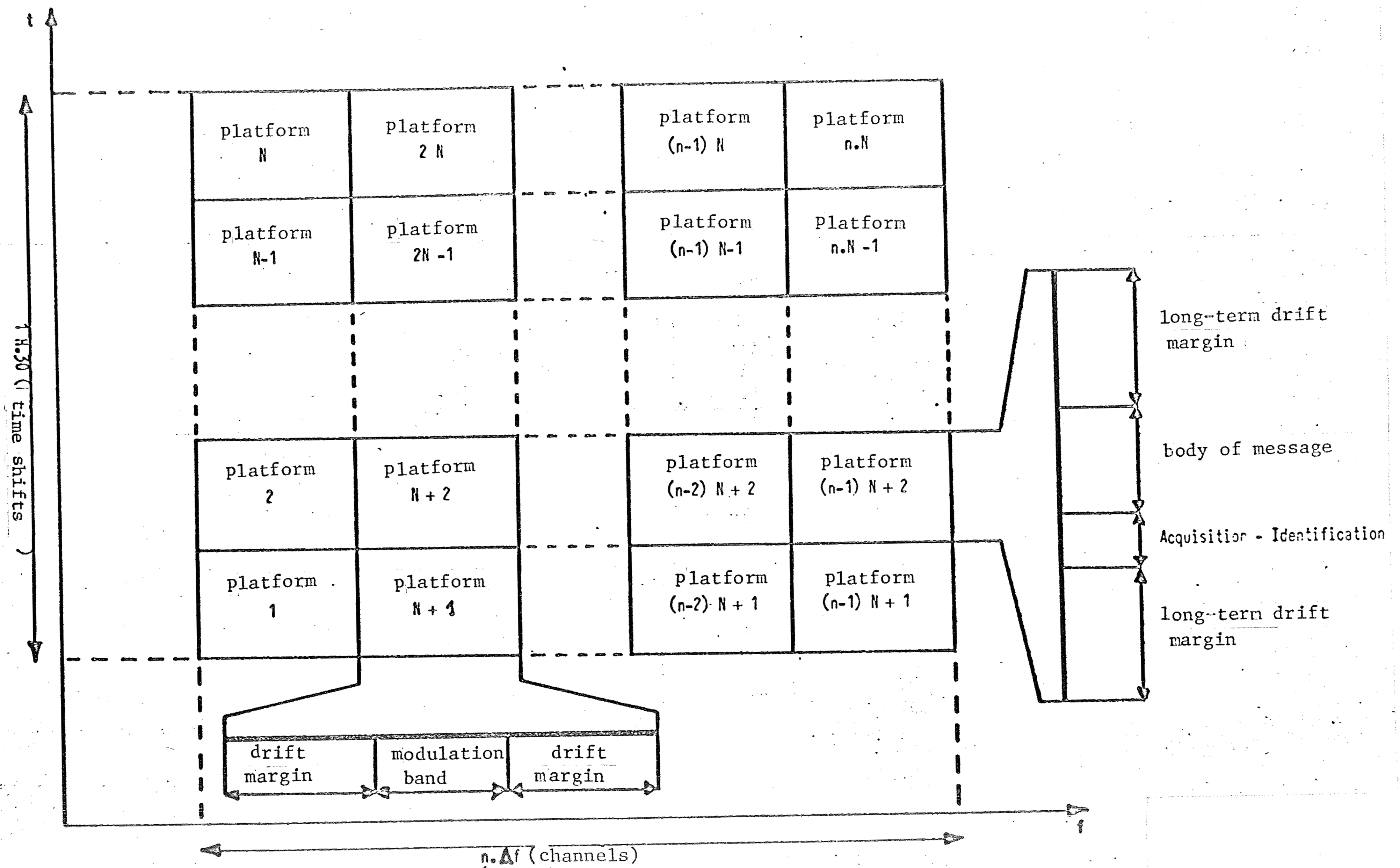


Figure 3.2. DISTRIBUTION OF SHIFT-TRANSMITTING PLATFORMS

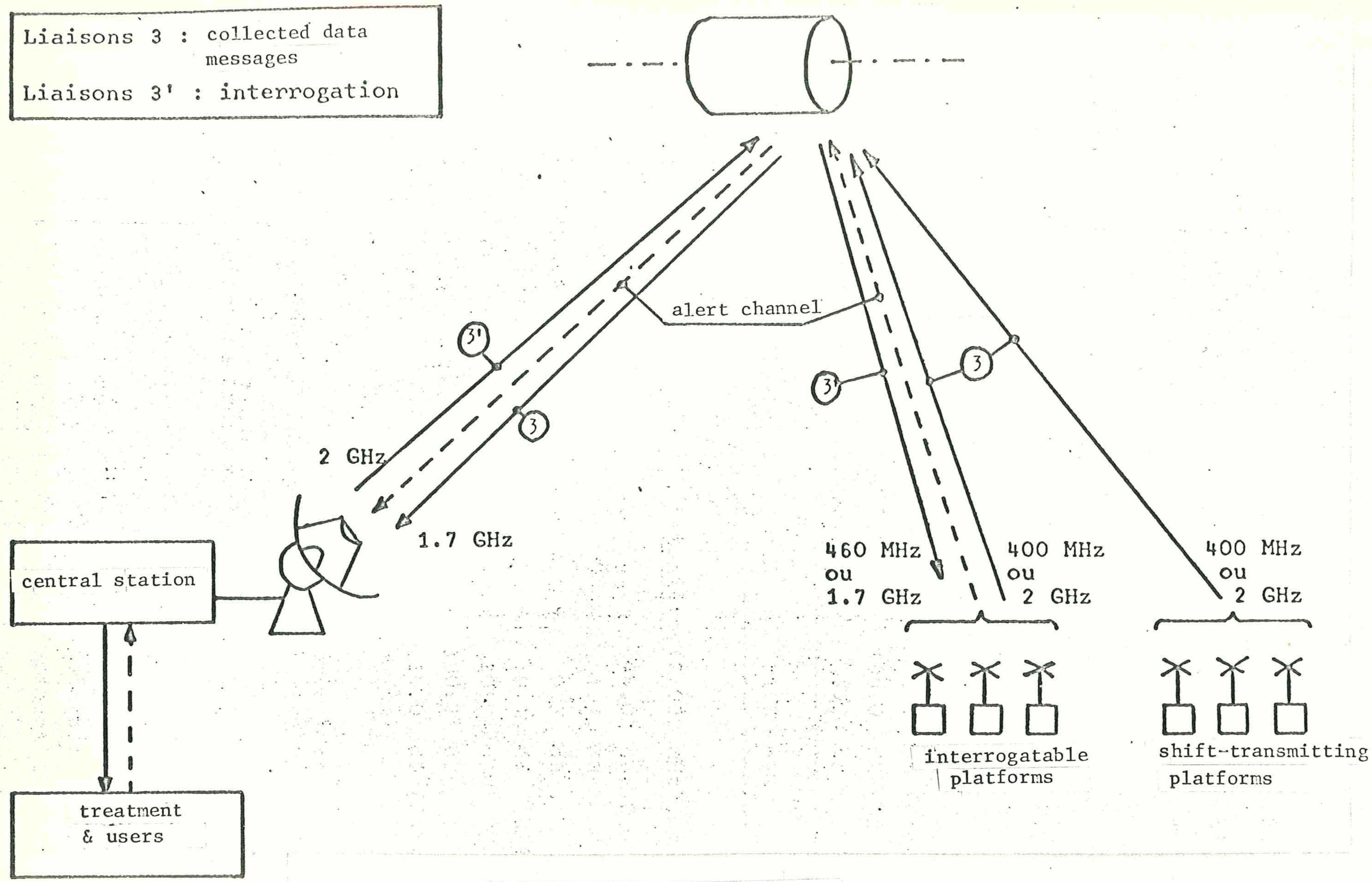


Figure 3.3. DATA GATHERING

of each 1-1/2 hour cycle, and remain tuned to it throughout the cycle. Each platform transmits its message when it recognizes its address. Interrogations and replies go through different channels (duplex operation). One or more channels are reserved for alert messages. The alert channels are permanently available, even when the repeater is used for other than data-gathering purposes.

3.2.3. Some estimated characteristics /3.7

The system is currently studied for a capacity of 4000 platforms, of which:

— 3000 platforms transmit in shifts,

— 100 platforms are interrogatable, including 100 alert platforms.

The 4000 messages will reach the central station in 1-1/2 hours, every 6 hours.

— Each channel will have a capacity of 75 bits/s.

— Message length may be variable depending on the type of platform between 256 and 4096 bits.

— The total number of channels n, as well as their bandwidth ΔF and the number of messages N which can be transmitted in 1-1/2 hour in each channel, are not yet determined. They depend on the frequency stabilities which can be achieved in the different levels of the system. This problem occurs primarily for platforms transmitting by shifts needing to be synchronized by a clock inside.

— There are still two options, as far as the frequencies are concerned used for the following communications:

. Central station-to-satellite: 1700 MHz ↘ 2000 MHz ↗ (approx.)

. Satellite-to-platforms: 1700 MHz ↘ 2000 MHz ↗

or 460 MHz ↘ 400 MHz ↗

The UHF option has the advantage of being a well-known engineering technique, but S-band option allows a considerable simplification in the satellite (particularly, a single counter-rotating antenna).

— The estimated platform characteristics vary by type. The radiated output (PIRE) will be at least 43 dBm for the buoys. This radiated output corresponds to the use of an omnidirectional antenna (G = 0 dB) and a 20 W transmitter. The radiated power of the ground or shipboard platforms /3.8 may be somewhat higher:

. through the use of a directional antenna (ground platforms),

. through using a more powerful transmitter (shipboard platforms).

The reception noise temperature (for interrogated platforms) is evaluated at approximately 1050° both for UHF and S-band. For reference, the communications balances are shown in Tables III through VII.

TABLE III

ALL S-BAND OPTION

INTERROGATION

1) Central Station-to-Satellite Link (2,000 MHz)

SC transmitted power		40.0 dBm
Net SC gain		42.8 dB
Propagation loss	-	190.2 dB (Elevation 30°)
Atmospheric loss	-	0.1 dB (Elevation 30°)
Polarization loss	-	0.3 dB
Satellite net gain	+	14.0 dB
SL received signal strength .	-	93.8 dBm
SL noise temperature		29.8 dB °K
Boltzmann constant k	-	198.6 dB1/Hz °K
SL noise strength	-	168.8 dBm/Hz
P/N_o		75.0 dB/Hz

2) Satellite-to-Platform Link (1,700 MHz)

	5° Buoy Elevation	90° Buoy Elevation	Inhibited Platforms 5° El.
SL transmission strength	43.0 dBm	43.0 dB	43.00 dB
SL net antenna gain	12.0 dB	15.0 dB	12.0 dB
Propagation loss	- 189.5 dB	- 188.2 dB	- 189.5 dB
Atmospheric loss	- 1.0 dB	- 0.1 dB	- 1.0 dB
Polarization loss	- 0.7 dB	- 0.7 dB	- 0.7 dB
Net platform gain	0.0 dB	0.0 dB	+ 10.0 dB

(table con't. on next page).

TABLE III (CON'T.)

	5° Buoy Elevation	90° Buoy Elevation	Inhibited Platforms 5° El.
Received signal strength	- 136.2 dBm	- 131.0 dBm	- 126.2 dBm
Platform noise temperature ..	30.0 dB °K	30.0 dB °K	30.0 dB °K
k	- 198.6 dBm/Hz°K	- 198.6 dBm/Hz°K	- 198.6 dBm/Hz°K
Noise strength	- 168.6 dBm/Hz	- 168.6 dBm/Hz	- 168.6 dBm/Hz
P/N_o	+ 32.4 dB/Hz	37.6 dB/Hz	42.4 dB/Hz
P/N_o total	+ 32.4 dB/Hz	37.6 dB/Hz	42.4 dB/Hz

TABLE IV

ALL S-BAND OPTION

REPLY

1) Platform-to-Satellite Link (2,000 MHz)

Buoy transmitted output		43.0 dBm
Buoy net gain		0.0 dB
Propagation loss	-	190.9 dB (Elevation 5°)
Atmospheric loss	-	1.0 dB (Elevation 5°)
Polarization loss	-	0.7 dB
SL antenna net gain		12.0 dB
SL received strength	-	137.6 dBm
Satellite noise temperautre .	+	29.8 dBm °K
Boltzmann constant	-	198.6 dBm/Hz °K
SL noise strength	-	168.6 dBm/Hz
P/N_o		31.2 dB/Hz

2) Satellite-to-Central Station Link (1,700 MHz)

Satellite output strength ...		43.0 dBm
Satellite antenna net gain ..		14.0 dB
Propagation loss	-	190.2 dB (Elevation 30°)
Atmospheric loss	-	0.1 dB (Elevation 30°)
Polarization loss	-	0.3 dB
Central Station net gain		42.8 dB
SC received strength	-	90.8 dBm
SC noise temperature		23.6 dB °K
k	-	198.6 dBm/Hz °K
SC noise strength	-	175.0 dBm/Hz
P/N_o		84.2 dB/Hz
Total P/N_o		31.2 dB/Hz

TABLE V

"S/UHF" BAND OPTION

1) Central Station-to-Satellite Link (2,000 MHz)

SC power transmitted .	40.0 dBm	
SC net gain	42.8 dB	
Propagation loss	- 190.2 dB	(Elevation 30°)
Atmospheric loss	- 0.1 dB	(Elevation 30°)
Polarization loss	- 0.3 dB	
Satellite net gain ...	14.0 dB	
Received signal strength	- 93.8 dBm	
SL noise temperature .	29.8 dB-K°	
k	- 198.6 dB/Hz-K°	
SL noise strength	- 168.8 dB/Hz	
P/N_o	75.0 dB/Hz	

2) Satellite-to-Platform Link (466 MHz)

	5° Buoy Elevation	90° Buoy Elevation	Inhibited Platforms 5° El.
SL transmits strength (15 W)	41.8 dBm	41.8 dB	41.8 dB
SL antenna gain	5.0 dB	7.0 dB	5.0 dB
Propagation loss	- 178.2 dB	- 176.9 dB	- 178.2 dB
Atmospheric loss	- 0.3 dB	- 0.1 dB	- 0.3 dB
Polarization	- 1.5 dB	- 1.5 dB	- 1.5 dB
Platform net gain	0.0 dB	0.0 dB	+ 10.0 dB

(table con't. on next page)

TABLE V (CON'T.)

	5° Buoy Elevation	90° Buoy Elevation	Inhibited Platforms 5° El.
Received signal strength	- 133.2 dBm	- 129.7 dBm	- 123.2 dBm
Platform noise temperature	30.0 dB-°K	30.0 dB-°K	30.0 dB-°K
k	- 198.6 dBm/Hz-°K	- 198.6 dBm/Hz-°K	- 198.6 dBm/Hz-°K
Noise strength	- 168.6 dBm/Hz	- 168.6 dBm/Hz	- 168.6 dBm/Hz
P/N_o	35.4 dB	38.9 dB	45.4 dB
Total P/N_o	35.4 dB/Hz	38.9 dB	45.4 dB

TABLE VI

"S/UHF" BAND OPTION

REPLY

Platform-to-Satellite Link (402 MHz)

Buoy Transmits strength		43.0 dBm	
Buoy net gain		0.0 dB	
Propagation loss	-	177.0 dB	(Elevation 5°)
Atmospheric loss	-	0.3 dB	(Elevation 5°)
Polarization loss	-	1.5 dB	
Satellite antenna net gain ..	-	5.0 dB	(Elevation 5°)
Satellite received strength .	-	130.8 dBm	
Satellite noise temperature .	+	29.5 dB °K	
k	-	198.6 dBm/Hz °K	
Satellite noise strength		169.1 dBm/Hz	
C/N_o		38.3 dB/Hz	

N. B. — The Satellite-to-Central station communications balance is the same as shown in Table IV.

IV. OPERATIONAL COMMUNICATIONS

4.1. Telemetry and remote control /4.1

Control of the satellite during its different orbital phases will be carried out by biphase PCM telemetry transmitted at 136 MHz:

— 16 bits/s for a reduced power transmission of 1 W,

— 64 bits/s for a 10 W transmission (especially for the transfer and stationing phases).

Command from the ground for the different operational modes anticipated for the satellite will require the transmission of remote-control orders for immediate execution and also remote-assignment of numerical messages. To satisfy these requirements, the TDCS is not suitable, and it would appear preferable to adopt the new PCM-FSK standard now being defined in Europe.

Communication will be carried out at 148 MHz.

4.2. Tracking /4.2

During the transfer and stationing phases, satellite tracking is accomplished by the Diana interferometry stations of the CNES network by listening to the satellite control telemetry.

Once the satellite is on station, it is planned that its precise position should be found by a distance measurement from the central station using the 2 GHz on-board transponder.

The use of laser reflectors would allow us to obtain excellent tracking accuracy. This solution is under study as an option.

V. THE SATELLITE

5.1. General remarks

The preceding sections have given a description of the satellite equipment specifically for missions 1, 2 and 3, that is:

— the radiometer and the image transmission link,

— the transponder.

In the following, all the other equipment on board will be described which is necessary for the operation of the satellite and for its control from the ground, i.e.:

— the structure of the satellite itself with the facilities for temperature control,

— the navigation subsystem,

— supply

— antennas,

— the apogee motor,

— finally, the subsystem composed of the equipment used for operational communications between the vehicle and the station network.

5.2. Characteristics of the satellite /5.2

The METEOSAT satellite will be stationed (and maintained in position) rotating at 100 rpm around an axis parallel to the line of the Earth's poles.

It will appear in the form of a cylinder covered with solar cells, pierced by a lateral opening for Earth sightings, and will be constructed around two basic pieces of equipment: the radiometer and the apogee motor which are placed one on top of the other on the axis of the satellite.

The radiating elements of the counter-rotating antenna are to occupy a part of the lateral surface.

The first architectural studies of the satellite showed that because of its weight (approx. 260 kg.) and its volume, METEOSAT will have to be launched by a Thor Delta of the new so-called "4 digit" series with 9 auxilary engines on the first stage (Delta 2913 or 2914) able to place up to 595 kg into transfer orbit. This version of the MacDonnell Douglas launcher will be equipped with an 8-foot diameter envelope which will apparently become the standard type after October, 1973 (Delta Manual, February, 1971).

The large diameter of the envelope allows us to obtain a stable configuration for the satellite (inertia ratio C/A greater than 1) and a sufficient solar generator surface for the mission. It is very improbable that those two limitations could be satisfied with the present version of the five-foot diameter envelope.

5.3. Navigation subsystem /5.3

The navigation subsystem plays an important part in the satellite. Its principal functions are:

— in the transfer orbit, to control the satellite + apogee motor complex, which is unstable,

— allow the exact stationing of the satellite with the correct attitude and rotational velocity,

— suppress all attitude perturbations,

— keep attitude, position and velocity of rotation at values compatible with image quality (see Par. II).

These limitations are difficult to satisfy.

To resolve the problem, the use of two command facilities is envisaged:

— the first using hydrazine as the ergol (thrust $\simeq$ 10 N) would be used for navigation into transfer orbit, orbit station control and rough orientation of the satellite axis on station,

— a second with a cold gas system (thrust $\simeq$ 0.1 N) would be used in fine orientation of the satellite axis and control of rotational speed.

A very low threshold nutation suppressor (fluid) would permit rapid suppression of parasitic motion induced by perturbations (especially telescope sweeps).

The command link for the navigational motors would have solar and terrestrial sensors as attitude detectors and an accelerometer.

Moreover, very fine attitude corrections (approx. 20") would be feasible through a stellar sensor mounted on one end of the satellite. Preprocessing of received images might be another very exact method of obtaining the vehicle attitude.

5.4. Supply

/5.4

Very special attention is paid to supplying the satellite, which is one of the most critical points in the scheme of the system feasibility. The necessary power for carrying out the missions is on the order of 120 W. Normally it will be supplied by the solar generator through a pre-set voltage distribution line. A Ni-Cd battery will serve as an energy memory in transfer orbit and will allow a back-up system during eclipses.

5.5. The antennas

The counter-rotating antenna will be made up of 32 generators with 4 elements radiating at 2 GHz, located on the periphery of the satellite, where it will occupy a cylindrical section 50 cm high. If the UHF option is chosen for the data-gathering mission, the corresponding antenna elements will be superposed on an S-band antenna.

5.6. The apogee motor

The apogee motor must give the satellite a velocity increment on the order of 1820 m/s.

A liquid ergol motor would be the lightest solution, but difficult to release. Moreover, the liquid sloshing back and forth would have a destabilizing effect on a dynamically unstable body ($C/A < 1$) like the satellite + apogee motor complex, making navigation still more difficult.

Thus, a powder motor is envisaged, the powder being ejected after combustion.

5.7. Operational equipment

The VHF antennae used on board would probably be whip antennae situated at one end of the satellite.

5.8. Recapitulation of the satellite's on-board equipment

The satellite will be composed of the following equipment:

— Structure with heat control devices,
— Hydrazine navigational device,
— Cold gas device,
— Nutation suppressor,
— Solar and terrestrial attitude sensors,
— Stellar sensor,
— Solar generator,
— Battery,
— Protection, regulation and conversion circuits,
— Multi-channel radiometer,
— Image coder,
— Memory,
— Clock,
— 1.7 GHz image transmitter,
— 2 GHz transponder (with 400 MHz option),
— 2 GHz counterclockwise antenna (with 400 MHz option),
— VHF remote control receiver and decoder,
— Set of VHF antennae,
— Laser reflectors, (optional),
— Powder apogee motor.

5.9. Weight balance /5.7

A first evaluation of the satellite's weight balance is as follows:

— Complete radiometer unit	53 kg
— Structure	48 kg
— Navigational subsystem	52 kg
— Supply subsystem	28 kg
— Electronic equipment	12 kg

— Counter-rotating antenna	30 kg
— Allowance for cable and balancing	15 kg
— VHF equipment	7 kg
— Stellar sensor	6 kg
— Margin for contingencies	9 kg
	260 kg

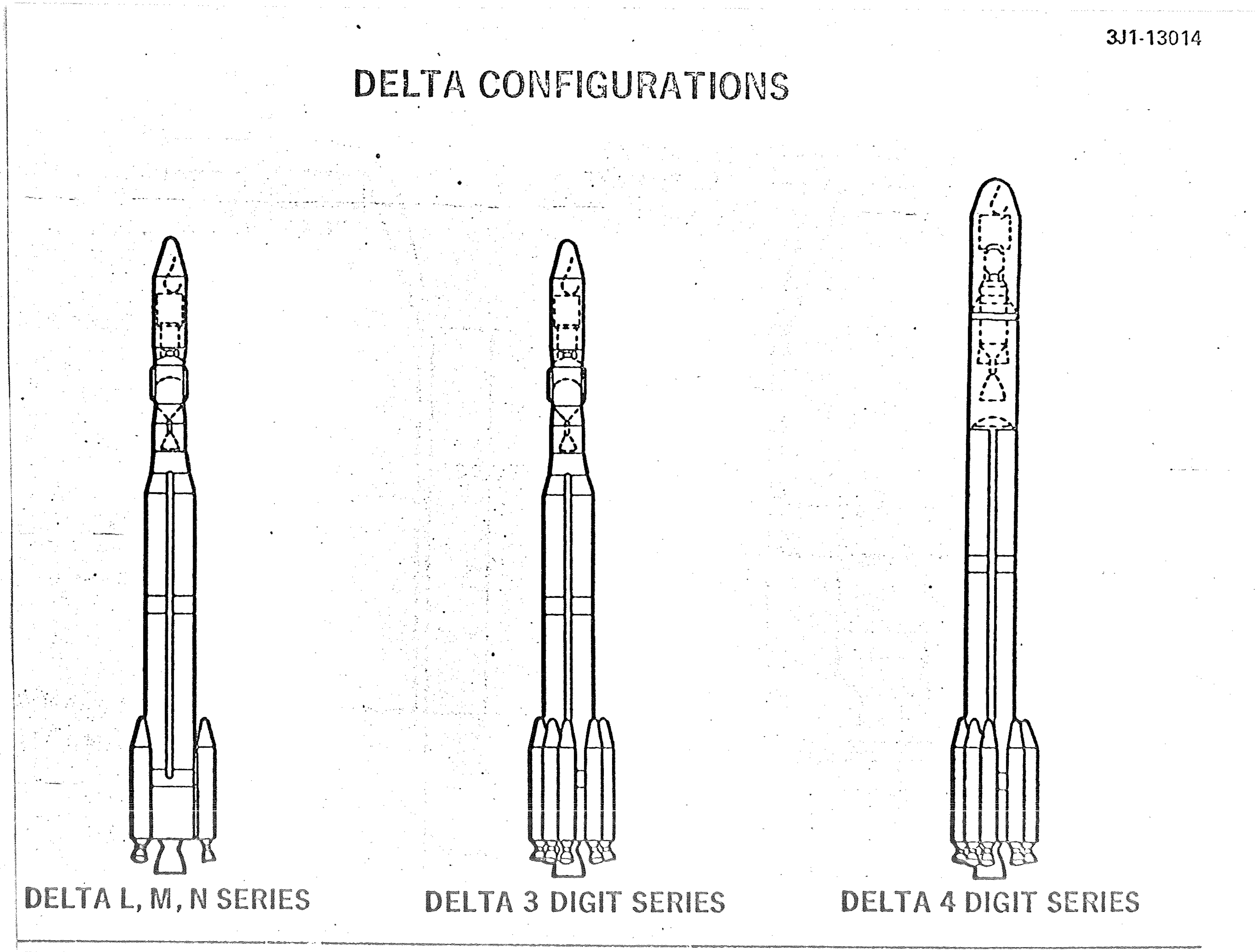

3J1-13014
DELTA CONFIGURATIONS
DELTA L, M, N SERIES
DELTA 3 DIGIT SERIES
DELTA 4 DIGIT SERIES

Figure 5.1.

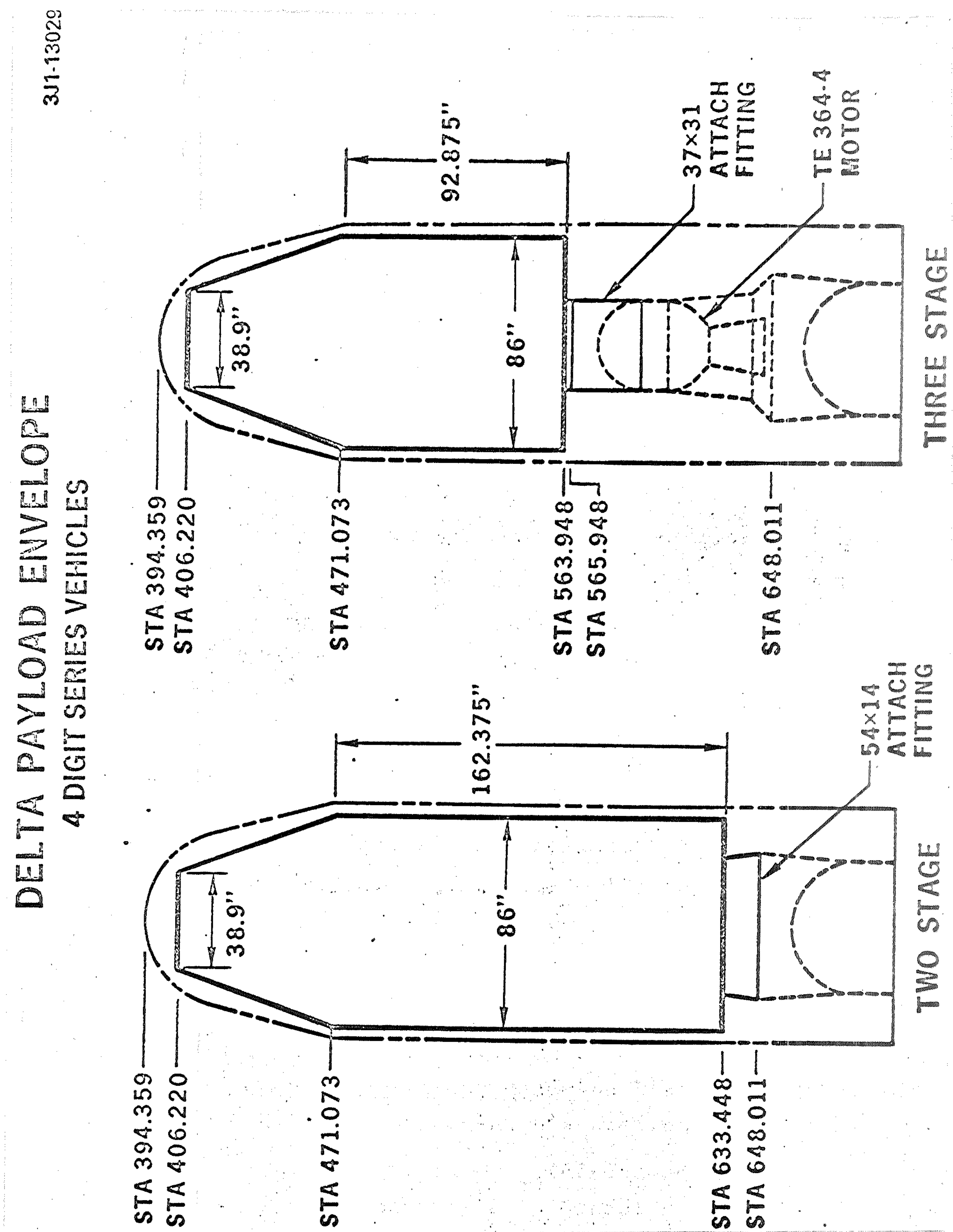

DELTA PAYLOAD ENVELOPE
4 DIGIT SERIES VEHICLES
3J1-13029
STA 394.359
STA 406.220
STA 471.073
STA 633.448
STA 648.011
162.375"
38.9"
86"
54×14
ATTACH
FITTING
TWO STAGE
STA 394.359
STA 406.220
STA 471.073
STA 563.948
STA 565.948
STA 648.011
92.875"
38.9"
86"
37×31
ATTACH
FITTING
TE 364-4
MOTOR
THREE STAGE

Figure 5.2.

VI. ROLE AND GENERAL DESCRIPTION OF GROUND EQUIPMENT

6.1. Review of functions to be carried out

The ground equipment will have two distinct types of functions, namely:

— specific functions linked to the system's 3 missions as defined in the preceding sections,

— so-called operational functions, necessary for monitoring and control of the satellite.

6.1.1. Mission-related functions

Primarily, these include:

— Reception of rough images at 1700 MHz (Mission 1),
— Pretreatment of rough images,
— Transmission of meteorological documents at 2000 MHz (Mission 2),
— Reception of gathered data and interrogation of platforms at 1700 and 2000 MHz (Mission 3).

6.1.2. Operational functions

— Reception of house-keeping telemetry at 136-138 MHz,
— Transmission of remote-control orders at 148-149 MHz,
— Interferometry tracking at 136-138 MHz,
— Distance measurement at 1700-2000 MHz.

a) The operational functions will be carried out primarily (Telemetry and Remote-Control) by means of the present CNES VHF network, including six stations situated at:

Pretoria	(South Africa)
Brazzaville	(Congo)
Ouagadougou	(Upper Volta)
Canary Islands	
Bretigny	(France)
Kourou	(French Guiana)

The extent of this network allows adequate coverage and redundancy both during launching of the satellite and during its actual lifetime in synchronous orbit.

b) Methods of VHF tracking include two interferometers located, respectively, at Pretoria and Kourou. These VHF tracking facilities appear sufficient to carry out satellite tracking during the launch phase. A study has shown that the apogee maneuvering (primary injection into synchronous orbit) was possible with such facilities, after the fourth apogee.

These facilities will be inadequate, however, for the satellite utilization phase, since image preprocessing requires high accuracy in tracking. This is why the use or development of new facilities is contemplated:

— Solution 1: S-band angular tracking, using data on the attitude of the central station plus the additional use of several distance measurements by a laser station.

— Solution 2: S-band angular tracking and distance measurements by S-band electronic means from the central station. This distance measurement would use connections already in existence for missions 2 and 3.

— Solution 3: Three S-band distance measurements taken at the central station (master station) and by means of two transponders (slave stations) in the VHF network stations. This third solution would allow a precise geometrical determination of the subsatellite point, in contrast to the dynamic treatment required by the first two solutions. The equipment requirements are more complicated, however.

Currently the most likely solution is Solution 2.

6.2. Organization of ground equipment

In addition to the existing VHF network, ground equipment would be regrouped in two primary centers:

6.2.1. Central station

The central station would include all the equipment for carrying out all S-band communications (1700-2000 MHz) with the satellite, namely:

— the connection for reception and acquisition of rough images, as well as equipment for recording and visualization for monitoring.

— the connection for organizing and transmission of meteorological documents (low and high definition) as well as reception equipment for monitoring,

— the connection for reception and acquisition of collected data and equipment for elaboration and transmission of interrogation messages,

— distance-measuring equipment,

— various monitoring accessories and equipment.

Figure 6.1 shows a block diagram of the central station.

The station will be equipped with a single Ø = 12 m diameter antenna. It will be automatically pointed, and its attitude data will be used for satellite tracking.

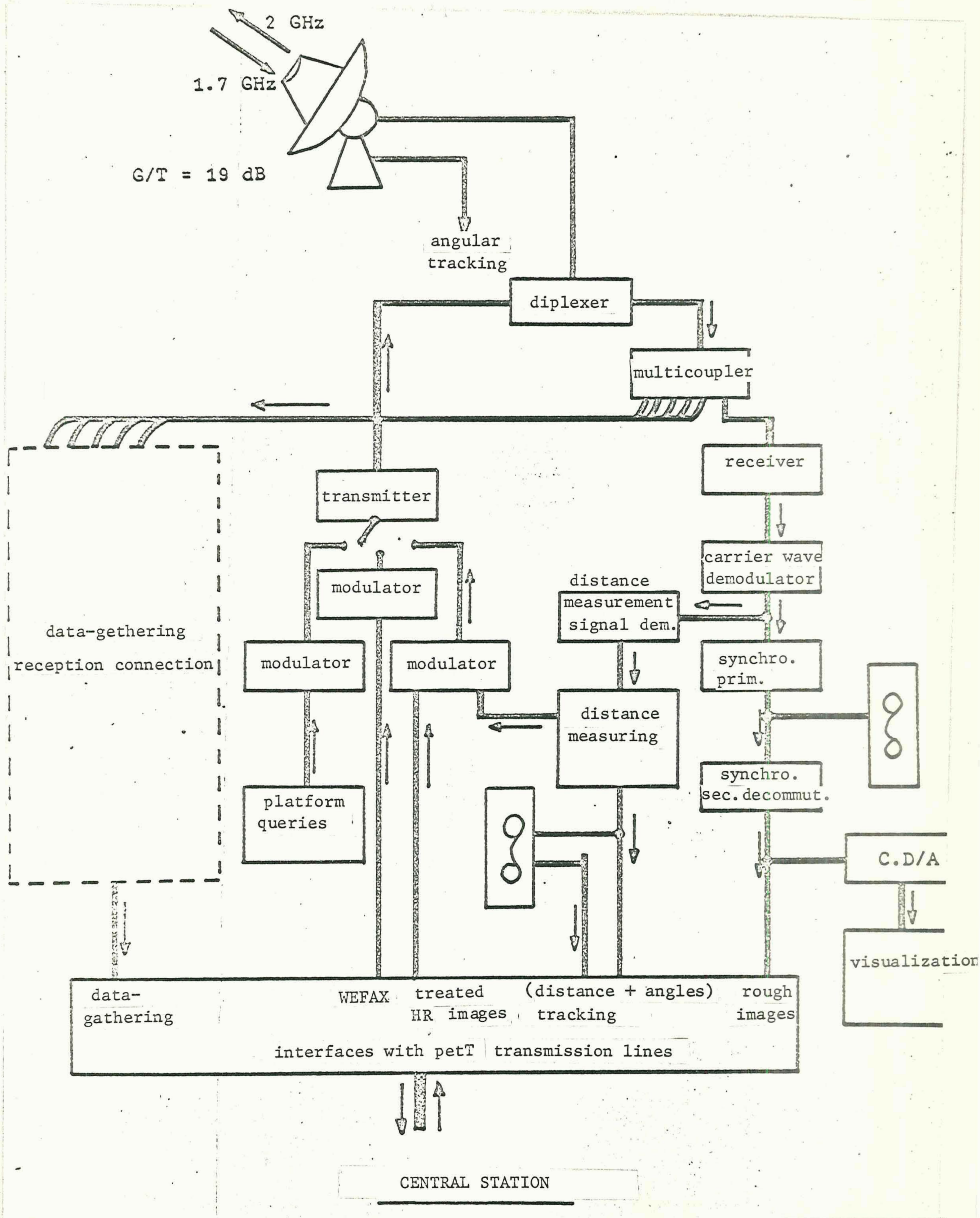

2 GHz
1.7 GHz
G/T = 19 dB
angular tracking
diplexer
multicoupler
receiver
transmitter
carrier wave demodulator
distance measurement signal dem.
modulator
modulator
modulator
synchro. prim.
data-gathering reception connection
distance measuring
platform queries
synchro. sec. decommut.
C.D/A
visualization
data-gathering
WEFAX
treated HR images
(distance + angles) tracking
rough images
interfaces with petT transmission lines
CENTRAL STATION

Figure 6.1.

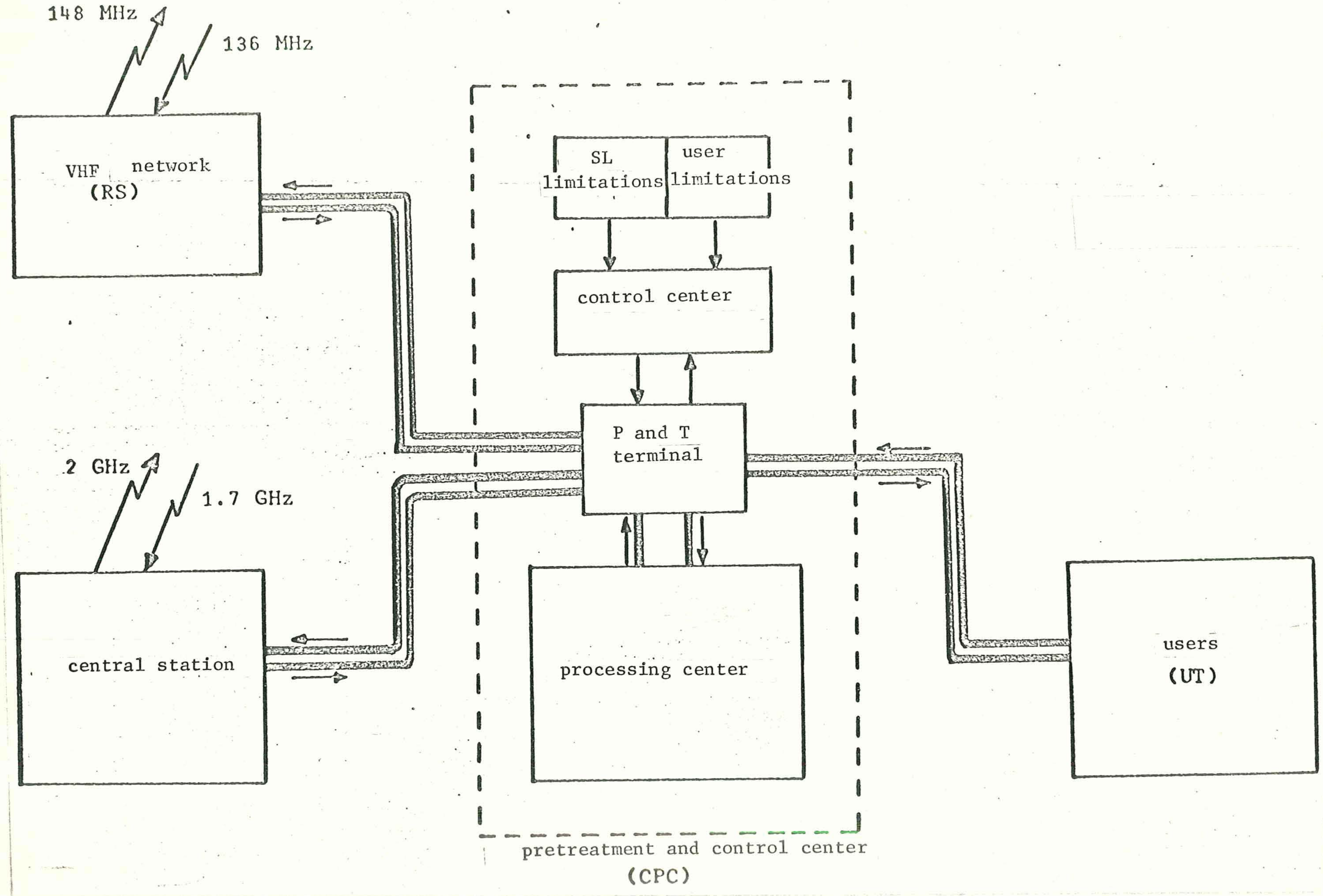


Figure 6.2. ORGANIZATION OF GROUND EQUIPMENT

The estimated reception noise temperature is approximately 230°K.

The central station is connected to the preprocessing and control center by a number of data transmission lines (Figure 6.2.).

6.2.2. Preprocessing and control center

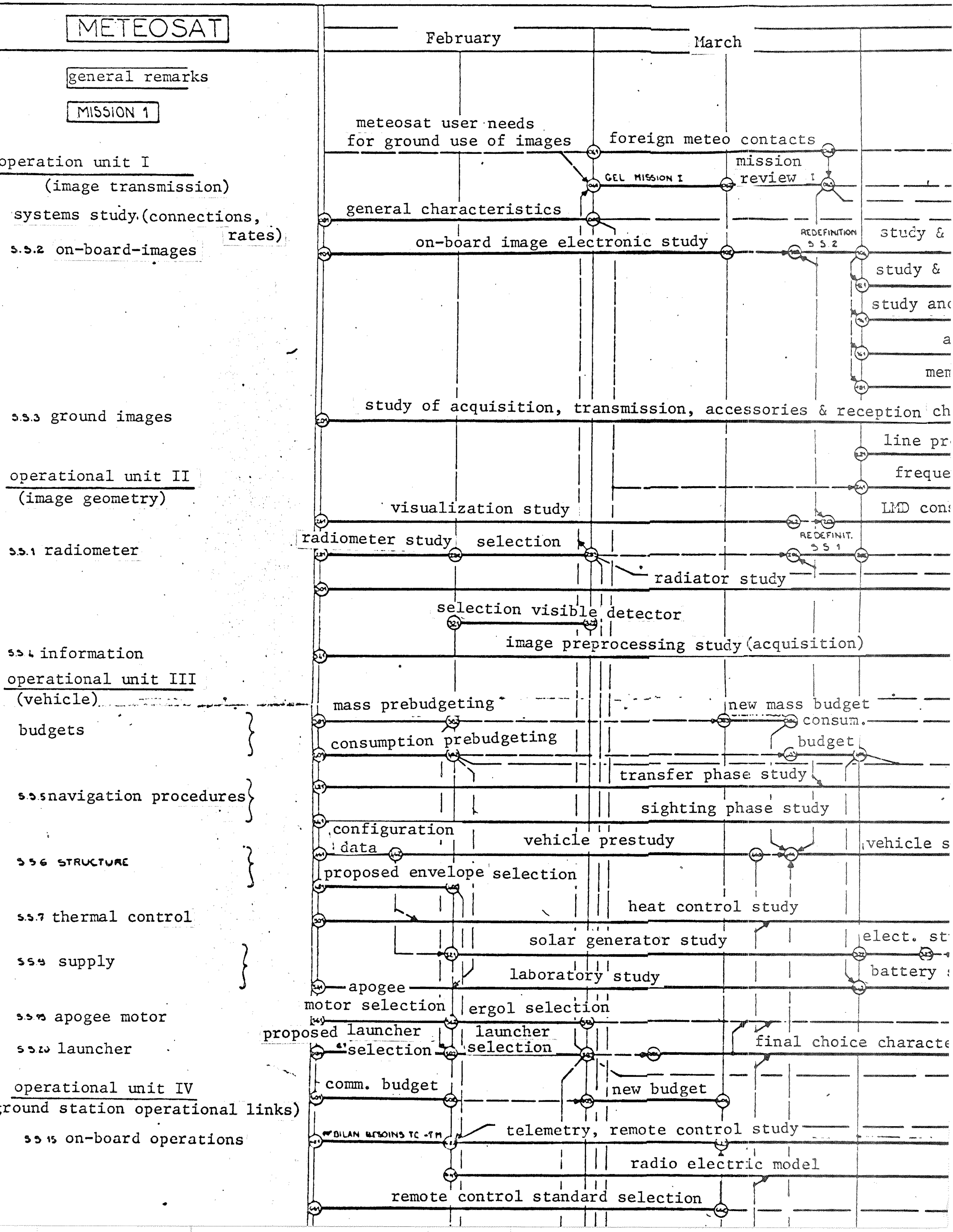
This center will contain the primary means of computation and the facilities for coordination of monitoring and guidance of the satellite.

The computer facilities will allow primarily the preprocessing of rough images. The purpose of this preprocessing is to remove all error induced by the system from the rough images:

— imperfections due to the orbit and attitude of the satellite,

— imperfections in the transmission connection,

and to put the images in an easily usable form for the users.



METEOSAT
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MISSION 1
February
March
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(image transmission)
systems study (connections, rates)
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5.5.3 ground images
operational unit II
(image geometry)
5.5.1 radiometer
5.5.4 information
operational unit III
(vehicle)
budgets
5.5.5 navigation procedures
5.5.6 STRUCTURE
5.5.7 thermal control
5.5.9 supply
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5.5.15 on-board operations
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study &
study and
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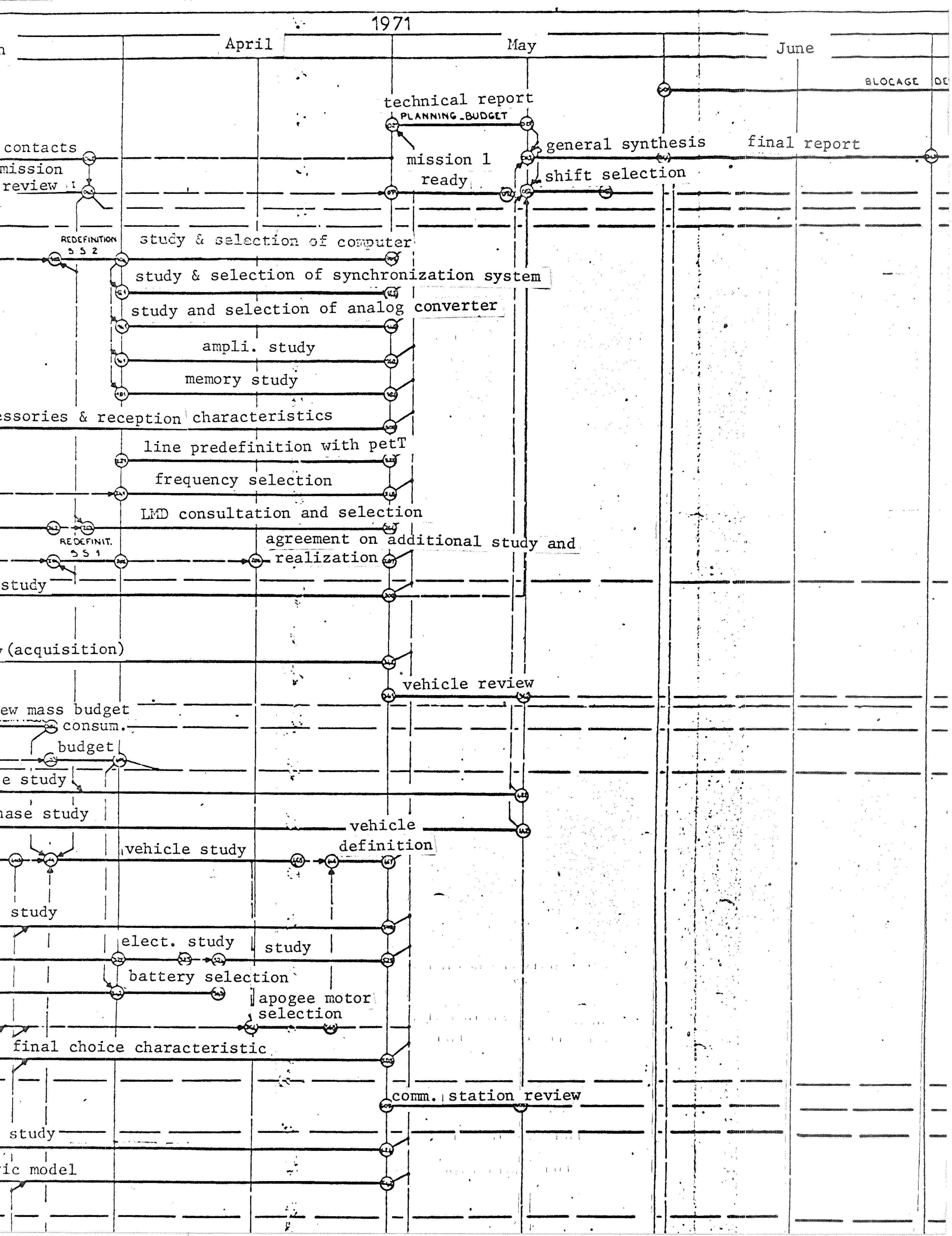
LMD cons
radiometer study
selection
REDEFINIT. 5.5.1
radiator study
selection visible detector
image preprocessing study (acquisition)
mass prebudgeting
new mass budget
consum. budget
consumption prebudgeting
transfer phase study
sighting phase study
configuration data
vehicle prestudy
vehicle s
proposed envelope selection
heat control study
solar generator study
elect. st
laboratory study
battery
apogee motor selection
ergol selection
proposed launcher selection
launcher selection
final choice characte
comm. budget
new budget
BILAN BESOINS TC-TM
telemetry, remote control study
radio electric model
remote control standard selection



1971
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May
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BLOCAGE DE
technical report
PLANNING_BUDGET
contacts
mission
review
general synthesis
final report
mission 1
ready
shift selection
REDEFINITION
S S 2
study & selection of computer
study & selection of synchronization system
study and selection of analog converter
ampli. study
memory study
essories & reception characteristics
line predefinition with petT
frequency selection
LMD consultation and selection
REDEFINIT.
S S 1
agreement on additional study and
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study
(acquisition)
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vehicle study
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battery selection
apogee motor
selection
final choice characteristic
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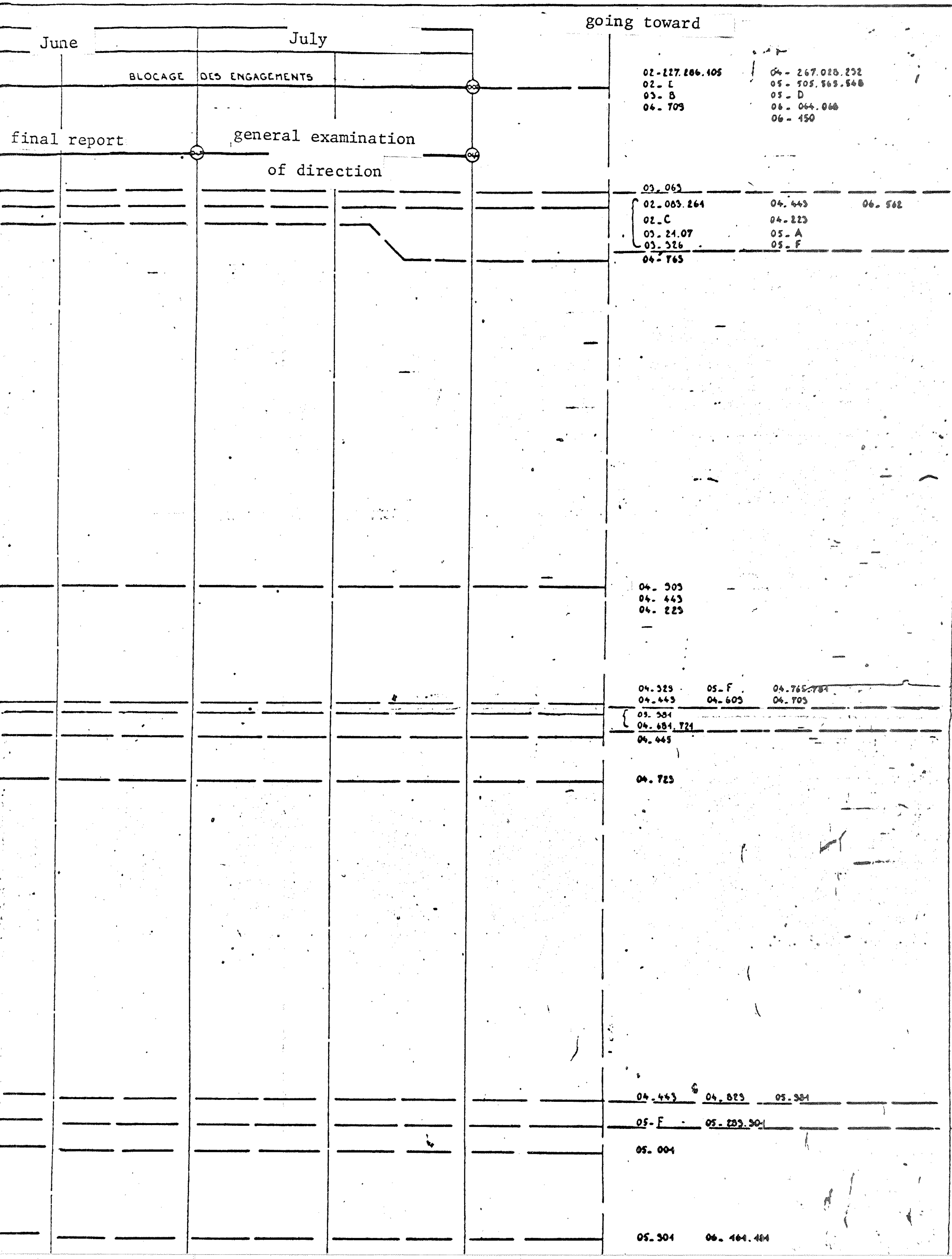

June
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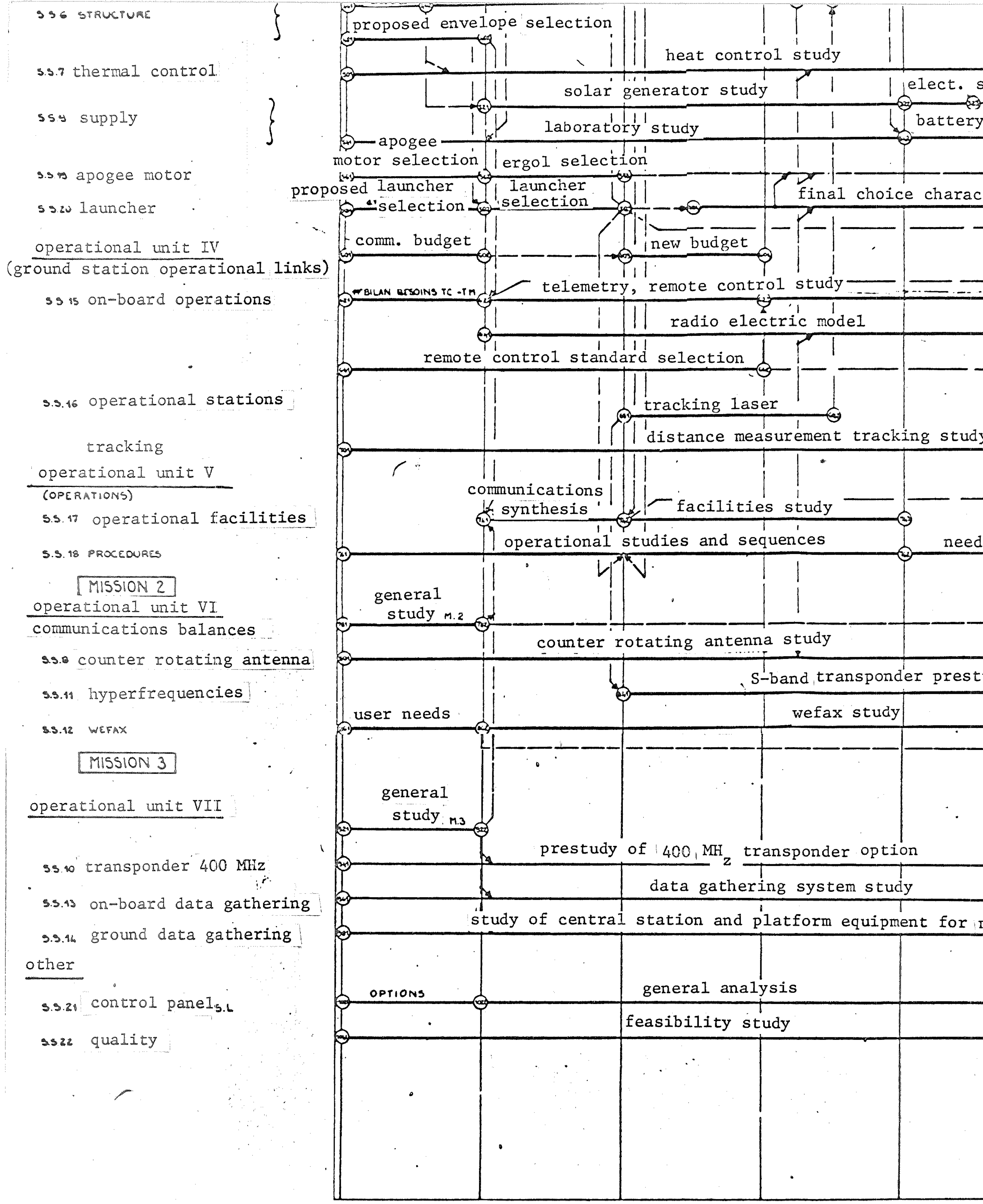
going toward
BLOCAGE DES ENGAGEMENTS
02-227.286.405
02- E
03- B
04- 709
04- 267.028.232
05- 505.565.568
05- D
06- 044.068
06- 450
final report
general examination
of direction
03.063
02.083.264
02.C
03.24.07
03.326
04.763
04.443
04.223
05.A
05.F
06.562
04.503
04.443
04.223
04.323
04.443
05.F
04.609
04.765.784
04.703
03.584
04.684.724
04.445
04.723
04.443
04.823
05.384
05.F
05.283.304
05.004
05.304
06.464.484



5.5.6 STRUCTURE
5.5.7 thermal control
5.5.5 supply
5.5.19 apogee motor
5.5.20 launcher
operational unit IV
(ground station operational links)
5.5.15 on-board operations
5.5.16 operational stations
tracking
operational unit V
(OPERATIONS)
5.5.17 operational facilities
5.5.18 PROCEDURES
MISSION 2
operational unit VI
communications balances
5.5.9 counter rotating antenna
5.5.11 hyperfrequencies
5.5.12 WEFAX
MISSION 3
operational unit VII
5.5.10 transponder 400 MHz
5.5.13 on-board data gathering
5.5.14 ground data gathering
other
5.5.21 control panel S.L
5.5.22 quality
proposed envelope selection
heat control study
solar generator study
elect. s
laboratory study
battery
apogee
motor selection
ergol selection
proposed launcher
selection
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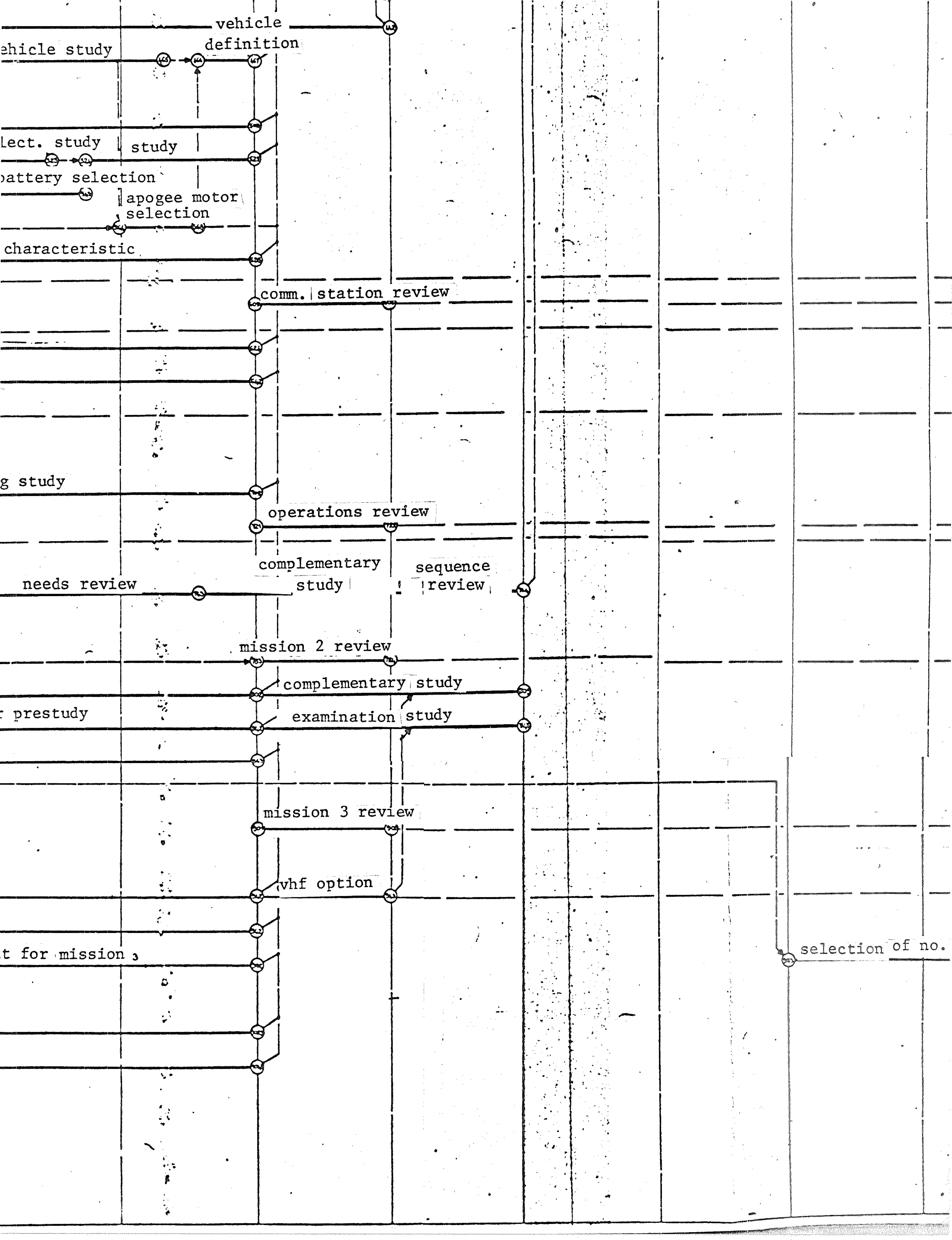
BILAN BESOINS TC -TM
telemetry, remote control study
radio electric model
remote control standard selection
tracking laser
distance measurement tracking study
communications
synthesis
facilities study
operational studies and sequences
need
general
study M.2
counter rotating antenna study
S-band transponder prest
user needs
wefax study
general
study M.3
prestudy of 400 MHz transponder option
data gathering system study
study of central station and platform equipment for
OPTIONS
general analysis
feasibility study



vehicle
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apogee motor
selection
characteristic
comm. station review
g study
operations review
complementary
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review
needs review
mission 2 review
complementary study
prestudy
examination study
mission 3 review
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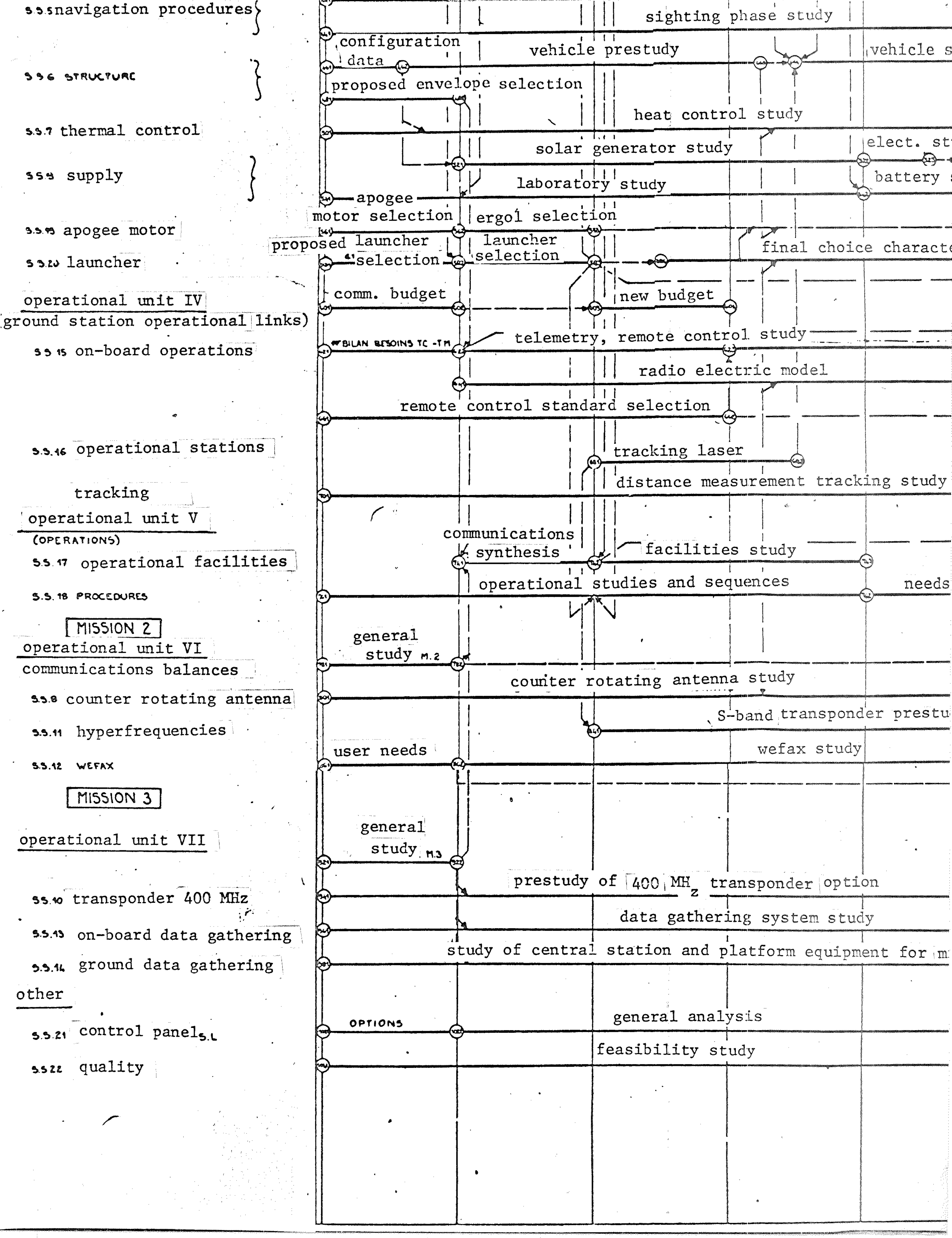

5.5.5 navigation procedures
5.5.6 STRUCTURE
5.5.7 thermal control
5.5.9 supply
5.5.19 apogee motor
5.5.20 launcher
operational unit IV
(ground station operational links)
5.5.15 on-board operations
5.5.16 operational stations
tracking
operational unit V
(OPERATIONS)
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5.5.18 PROCEDURES
MISSION 2
operational unit VI
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